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United States Department of Agriculture,
OFFICE OF THE SECRETARY.

Report No. 117.
Contribution from the Forest Service,
Henry S. Graves, Forester.

THE SUBSTITUTION OF OTHER MATERIALS FOR WOOD.

STUDIES OF THE LUMBER INDUSTRY.
PART XI.

BY

ROLF THELEN, *Engineer in Forest Products.*

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1917.

FEDERAL TRADE COMMISSION,
Washington, May 29, 1917.

The FORESTER,
U. S. Department of Agriculture,
Forest Service, Washington, D. C.

SIR: At the request of the Forest Service the Federal Trade Commission has examined the report of the Forest Service on The Substitution of Other Materials for Wood and recommends its publication.

The statistics and other facts in this report have been, for the most part, collected by the Forest Service, but the record of the hearings of this commission regarding conditions in the lumber industry, and other data in its possession regarding the organization of the industry, have been placed at the disposal of the Forest Service under the plan of cooperation which has been adopted by the Forest Service, the Bureau of Foreign and Domestic Commerce, and the Federal Trade Commission.

With the conclusions reached by the Forest Service with respect to the substitution of other materials for wood and the economic causes thereof the Federal Trade Commission is in agreement. For the particular statements of fact, however, the Federal Trade Commission assumes no responsibility. Nor does it consider itself limited to the conclusions reached by the Forest Service concerning matters peculiar to the commission's jurisdiction.

By order of the commission.

(Signed) L. L. BRACKEN, *Secretary.*

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THE SUBSTITUTION OF OTHER MATERIALS FOR WOOD.

THE USE OF WOOD IN THE UNITED STATES.

SOCIAL AND ECONOMIC CHANGES AFFECTING THE USE OF WOOD.

During the last 35 years the proportion of urban to rural population in the United States has increased from less than 30 to more than 46 per cent. Ground values in cities have risen in proportion. High values and the demand for the best service in dense centers of population have necessitated increasingly intensive use of space, and have led to a remarkable modification in forms of construction, to intensive study of forms and materials, to striking developments in architecture and engineering, and to highly specialized types of buildings. Wooden structures have been replaced by structures in which wood could be used only in part. The apartment house has replaced the detached wooden dwelling; and the steel-frame skyscraper of fireproof construction has taken the place of the old business block in which wood was an important construction material. Disastrous fires and the growing insistence upon fireproof construction have led to widely varying and increasingly stringent fire ordinances prohibiting, within certain prescribed limits, the use of wood for many purposes for which it was once used almost exclusively.

These constitute, however, only one phase of the changing ideas and demands as to forms of construction, and only one group of the economic and other forces which have led, particularly during the past decade, to a rapidly increasing substitution of iron, steel, cement, and other materials for lumber and other forms of wood, and, further, to the replacement of older forms of wood products, such as lumber, by those which are comparatively new, such as wood pulp. One of the most important groups of these forces centers around costs and the utility of the competing materials and the products into which they go. Lumber prices have increased more rapidly during the past 25 years than prices for most of its competitors.

Acknowledgment is here made of the splendid assistance rendered the writer by various members of the staff of the Forest Products Laboratory. Especial thanks is due to Mr. H. F. Weiss, former director, and Mr. F. J. Hallauer, engineer in forest products, for assistance in the preparation of the outline and for review and criticism of the finished manuscript; to Mr. H. E. Surface, engineer in forest products, who obtained the statistics on wall and plaster boards; and to Mr. G. S. Custer, computing clerk, who compiled much of the statistical data presented in the report. Acknowledgement is also made of assistance rendered by the Office of Industrial Investigations, the Bureau of the Census, the Geological Survey, and the American Iron and Steel Institute in supplying published and unpublished data.

For instance, a more or less regularly rising lumber price curve contrasted with a steadily falling cement price curve, covering the period of the development of manufacturing processes and the growth of the cement industry, is indicative of the conditions which have to a large extent made possible the very active competition of cement and its products with wood. The increase in wood prices, while due in part to the gradually decreasing purchasing power of money, which affects timberland values and lumber manufacture and distribution in all their phases, is due very largely also to the exhaustion of local supplies of timber. Higher transportation costs on lumber have resulted logically from the gradual exhaustion of forest resources in the regions near the center of population and lumber consumption, and the gradual shifting of lumber production in turn from the Northeast to the Lake States, to the South, and now, in its initial stages, to the Pacific Northwest.

Substitution in some cases has been due to lower costs. The fiber box has developed large markets at the expense of the wooden or shook box because it is cheaper; flour sacks cost less than the wooden barrel. On the other hand, many substitute roofings are more expensive than wooden shingles, but have absorbed a part of the shingle market in spite of this initial handicap. The purchaser, if he has a free choice, pays a higher price for a substitute for wood only when he believes that in the long run the utility of the substitute will be greater in lower maintenance charges or greater durability, in reduced risk, or in better appearance. These are the reasons why in many cases steel and cement at higher initial costs have replaced wood. Wood in some cases holds its place because of greater utility. The wooden railroad tie, because of a resiliency not yet duplicated, is practically unchallenged in its own field. The fiber box is lighter than the wooden box and pays correspondingly less freight. The cotton cement sack is under some conditions more convenient for handling than the larger and heavier barrel. The "safety first" agitation leads to the all-steel passenger train; and the demand for pure food leads in one case to the small substitute carton which goes unopened through all intermediaries from the manufacturer to the consumer, and in another to the wooden box as a maximum of protection from rodents, insects, and exposure.

The marketing of substitutes has in most cases been more aggressive and more efficiently directed in all of its numerous bearings than that of lumber and other older wood products. Organized advertising, in the lumber industry conspicuous mainly by its absence from all channels reaching the ultimate consumer, has, in many competing industries, fully kept pace with general American advertising development and in itself has made possible the growing utilization of a long list of substitutes. For substitutes, advertising

has been necessary in order to secure "a place in the sun," while the sponsors of many forms of wood have rested too securely in the belief that their products would continue to be necessities which could be depended upon to sell themselves without special effort.

In their efforts to create new fields and to enter fields already occupied, the substitute industries have been compelled to offer increased service in the form of exact data regarding the properties of their materials. Some of these industries have therefore expended large sums in scientific study of properties and processes and the best methods of utilization, and in attempts to improve the quality of their products. These have led to handbooks of exact information in convenient form and vouched for by accepted authorities, to detailed instructions concerning the use of the materials by trained as well as untrained men, to exact specifications, to the general standardization of manufacture to comply with these specifications, and to the formulation of procedure for requiring all manufacturers to conform to the standards established.

For lumber and other wood products, similar information has been comparatively lacking, and only now is being supplied by Government agencies as much as or more than by the industries concerned. For lumber, to begin with, there is not even uniformity in the names of different varieties of timber, and lumber grades and specifications are rarely understood outside of the industry. Milling specifications vary from one time to another, and between regions, and in part are imperfectly developed. Means have been provided in only a part of the industry to insure that lumber deliveries to purchasers are in accordance with the grades and specifications ordered, and to adjust differences between dealer and purchaser. For the rest, the purchaser must rely upon his own ability to secure what he specifies, or as a last resort appeal to the courts.

The entire situation in these respects has been a potent cause of substitution. Realization of the situation in the lumber industry has not kept pace with changing conditions. Much greater centralization in the industries producing many of the substitutes than in that producing lumber has unquestionably had its bearing upon the aggressive and consistent marketing of their products.

Substitution sometimes results from mechanical inventions. The steam engine has helped to make possible the immense steel hull of the modern steamship. The perfection of the gasoline engine and the development of the automobile have already cut nearly in half the horse-drawn vehicle industry in the United States. The products of the basic wood-using industries for which there has been no substitution are rare. It is essentially true, however, that no substitute has been found for the wooden railroad tie, for reasons already stated; and it is equally true of mining timbers.

The cumulative effect of these widespread changes in economic and industrial conditions has been an increased substitution for wood along many lines. Lumber is suffering from the competition of steel, cement, and other materials. Lumber and various other wood products, such as pulp and veneer, are competing actively with each other. In extreme cases, such as the sidewalk, wood and wood products have disappeared as active competitors. Within the last 25 years lumber has changed from a necessity like wheat, which was practically its old status, to one of many structural and factory materials competing for trade, and this is equally true of other wood products. Per capita consumption of lumber in the United States fell from about 516 board feet in 1906 to about 375 in 1915, and in some of the older States it has now reached a lower level; for instance, 206 feet in New York. Yet there is need for all of the timber in the United States. The timber shortage which has followed the exhaustion of the local supply has been one of the causes of high lumber prices and the decreasing use of wood. The total consumption of wood is far in excess of the growth.

SIGNIFICANCE OF THESE CHANGES TO THE PUBLIC AND TO THE INDUSTRIES.

The consuming public has, obviously, a very direct interest in the price of lumber, which is the resultant of competition not only of lumber cut by different mills and from different species and regions but also in a degree between lumber and its substitutes. It has an interest in other aspects of the situation also. The extent of the social and economic changes affecting the use of lumber and the direction these changes will take in the future form an important question of public economics, bearing upon the utilization of the forest resources, upon the stability and development of lumbering and of other wood-using industries, and upon the whole problem of insuring an adequate future supply of basic raw materials.

There are very direct relations between increasing substitution, a decreasing relative demand for lumber, intense competition among lumber producers, price limitations set by actual or potential competition from substitutes, recurring overproduction of lumber and price fluctuations, and general instability within the lumber industry. It is therefore desirable for all the wood-using industries to be in touch with the situation, and especially for the lumber industry to know the present facts and tendencies, in order that it may take them into account in the production and marketing of lumber.

A STUDY OF SUBSTITUTION.

The foregoing considerations, public and industrial, have led to the compilation of all the data obtainable, even if not wholly complete or exact, on the replacement of lumber and wood in other

forms. Though some data are given on substitutes for wood in other forms, the object of this publication is to deal primarily with substitutes for lumber. It has not been possible to make a complete census of substitutions for some of the articles discussed. In these cases a partial census, sufficient to show the general trend in production or consumption, has been taken, and the results are given for what they are worth.

The general principle followed in the study has been to regard as substitution the replacement of lumber or other forms of wood in uses for which it is now or was formerly employed, by other materials, including fiber and veneer products whose base substance is wood. This includes also the curtailment of the normal expansion of the markets for lumber, as broadly indicated by the production of the substitute.

Substitution is, therefore, only in part the replacement of wood by other basic materials. Various new wood-using industries are competing actively with the old, the veneer and fiber package with the wooden or shook box, the veneer barrel and the paper sack with the slack barrel. Thus the total replacement of wood in a form of use may be much less than the replacement of some one of the older wood products, such as lumber. New forms of construction for which wood is not suitable are not regarded as substitution, and no attempt is made to estimate the extent to which such changes or innovations have prevented the use of wood or absorbed markets which otherwise it might have supplied. Thus the steel used in the skeleton of the skyscraper and in the mammoth steamship of to-day is not regarded as a substitute, although unquestionably in both cases it has limited the use of wood. These are new forms of construction for which wood has never been used and for which probably it is not suitable.

A number of the materials discussed are substitutes for wood only in part. In many such cases it is impossible to draw the line exactly where substitution begins, although the extremes may be clear. This is true in such structures as ships, buildings, and bridges.

The general process of substitution has not necessarily involved a diminishing demand for wood in each of its many uses. In several forms of utilization, such as furniture and silo and windmill manufacture, the total consumption of wood has increased, although obviously in a smaller amount than if there had been no replacement.

This report covers substitution in 30 or more forms of use, which fall into three more or less distinct groups. The first group is called "Building and Construction," but is somewhat arbitrary, depending in a degree upon the form in which statistics are available. It includes planing-mill products, general millwork, rough and tem-

porary construction, building, sawed mining timber, and sawed railroad ties; and secondarily, fencing, sidewalks, roofing, and lath. Fencing and sidewalks are separated from the other classes of this group because substitution had been largely completed in these before it was well under way in the other wood products. Roofing and lath are separated because the substitutes do not replace lumber but wood in other forms.

The second group deals with various special manufactures or wood products in which the substitution has replaced either lumber or wood in other forms, or both. It includes boxes, railroad cars, furniture, vehicles, ships, silos, windmills, cooperage, fuel wood, and miscellaneous articles. The third group includes mainly forms of utilization in which the use of wood is growing in competition with other materials and the process of substitution is reversed. It includes the wooden-stave pipe, paving blocks, and wood pulp.

BUILDING AND CONSTRUCTION.

General building and construction are by far the largest consumers of lumber in the United States. Data secured by the Forest Service during the years 1910–1913 inclusive indicate that, on the basis of a total annual consumption of 38 billion board feet estimated for 1915, approximately 13 billion board feet were used in 1915 for planing-mill products, sash, doors, blinds, and general millwork, and approximately 14 billion feet in rough construction and building, or a total of 27 billion feet. The 14 billion includes sawed mining timber and ties, and all lumber used in building, temporary construction, and all classes of rough construction not specifically covered under other heads. This total is probably conservative. The classification is somewhat arbitrary and has been adapted to the form in which statistics on lumber consumption by classes are available. The use of lumber for general building and construction in preceding years probably bears somewhat the same ratio to the total lumber consumption for all purposes.

BUILDING AND CONSTRUCTION, OTHER THAN FENCING, SIDEWALKS, ROOFING, AND LATH.

The five principal building materials used in the United States are lumber, concrete, steel, brick, and clay products other than brick. The competition of these materials, following rapidly changing demands as well as rapidly changing conceptions of their utility has undergone a remarkable change during the last few decades. Brick, one of the oldest known construction materials, has always been a competitor of lumber, while concrete has been a material factor only since 1900. The present utility of these substances varies greatly. In part, they can be used interchangeably, as in the siding of dwelling houses, where the builder, depending upon his taste, the character of

the structure, building restrictions, initial costs, etc., uses lumber, brick, concrete, or tile. For the framework of the modern skyscraper steel alone is suitable; similarly, in large dams concrete can hardly be regarded as a substitute for wood. For some uses concrete is a substitute only in part, as in concrete floors, for the laying of which a certain amount of lumber is still required. For some purposes, such as dams, the use of concrete actually increases the demand for lumber, which is used to build the forms required in construction.

Factors Causing Substitution.

Before taking up the statistics of production, consumption, and substitution of the materials used in building and construction, some of the principal economic factors which have resulted in the present situation should be considered in greater detail. These include the effect upon rural construction of the gradual settlement of agricultural regions, the movement of population from country to city, building codes in urban construction, and finally, comparative utility and cost. These factors apply also, to a greater or less extent, to many of the classes of substitution treated under other heads.

SETTLEMENT OF AGRICULTURAL REGIONS.

The various stages in the settlement of different agricultural regions in the United States have overlapped, so that general statistics of construction for the entire country include old as well as new regions. This to a considerable extent conceals, in country-wide statistics, the effect of general tendencies in building. The general succession in building, in the timbered regions at least, is from the log house to the frame dwelling, and then to more permanent forms, such as brick, stone, or concrete. After settlement is well established per capita consumption of lumber falls off rapidly. In New York and Pennsylvania, representing the older, fully settled parts of the country, the per capita consumption now amounts to 206 and 292 feet of lumber, respectively; while in Montana, a State in which there now is a large amount of new building in addition to a large consumption of mining timber, it reaches 1,234, and in Oregon, 714 feet. The falling off in the older States is due largely to the completion of needed buildings, but it is also unquestionably due in part to greater proportional use of other materials.

MOVEMENT OF POPULATION FROM COUNTRY TO CITY.

The second economic factor, the movement of population from country to city, has had a much greater effect upon the character of construction. With the dividing line at towns of 2,500, the proportion of urban population in the United States has increased from 29.5 in 1880 to 46.3 in 1910. Highly increased demands for

service in its broadest sense, growing recognition of the common fire menace, and growing insistence upon safety in construction have led to an increasingly stringent public regulation of building, through special ordinances or building codes, in practically every city of more than 50,000 inhabitants in the United States and frequently in smaller cities.

Building codes.—Present-day building codes[1] in American cities give almost every conceivable variation in their comparative requirements for lumber and other materials. In general, however, there is a much greater variation in their requirements as to lumber than its competitors, because until recently little or no exact scientific data on the properties and qualities of wood have been available. In the case of steel and cement, thousands of dollars have been expended in the scientific determination of such data. The qualities of wood obviously vary greatly with the botanical species; and the utter confusion of names within the lumber industry (the use by lumbermen of several distinct names for the same species in different parts of the same region, and the use of the same name for distinct species from different regions) has led to a confusion at least as great in city codes and far greater in the minds of consumers.

Until recently there has been in the lumber industry no system of classification or grading for any species of structural timber, based upon strength, the prime requisite. Small wonder is it, then, to find in building codes such variations in allowable fiber stresses under similar conditions as from 1,200 to 2,495 pounds per square inch for yellow pine, a term which includes several species varying widely in strength, and from 600 to 1,800 pounds for hemlock; whereas the allowable fiber stresses in bending for rolled steel in buildings are practically uniform, or from a minimum of 15,000 pounds to a maximum of 16,250 pounds. With such wide variations for timber the enforcement of maximum requirements by municipal authorities may increase the cost of wood sufficiently to handicap it very seriously in competition with other structural materials. In general, the judgment of the individual inspector plays a much more important part in the case of wood, and tends to make the architect, after a few unsatisfactory experiences, hesitate to use wood when other materials are available, because of the difficulties and uncertainty of acceptance. From the standpoint of fire protection the requirements vary from absolute prohibition of the use of wood for specific purposes to its unrestricted use, and are based largely upon inexact, empirical knowledge. The fundamental difficulty in the use of wood under building codes lies in the absence of authentic information on which to base scientifically correct requirements.

[1] Provisions in Building Codes Relating to the Use of Structural Timber, by Howard F. Weiss and H. S. Betts, published in the Proceedings of the Forest Products Federation, Feb. 24 and 25, 1915.

COMPARATIVE UTILITY OR SERVICE.

The use of competing materials will ultimately depend mostly upon their utility, or service, and cost in comparison with wood. Scientific investigations will in time furnish exact information upon which to base judgment as to the comparative suitability of competing materials for various purposes because of their properties and their relative susceptibility to damage and destruction by fire. In other words, utility or service depends in part upon the inherent properties of the materials themselves and the extent to which these properties can be improved through scientific development. In part it depends also upon manufacturing specifications, which in the case of lumber are called grading rules, the adherence in manufacture to standard specifications, and the extent to which the properties of the material and the manner in which it can best be used are made common knowledge among consumers. In the case of many substitutes it is possible to control and improve basic properties, a factor acting to the disadvantage of wood which is a natural rather than a manufactured product. But in grading rules, manufacturing standards, and popular education concerning the properties and efficient uses of their products, all industries have a free hand and are more nearly on an equal basis.

The complexity of lumber grades has unquestionably been a handicap to that industry. Practically every region and species in the United States has its separate grading rules, sometimes more than one set. The number of grades has been increasing. The delimitations between grades can not be exact, and necessarily admit variations through the individual judgment of inspectors. The manipulation of grades as well as species is not uncommon. The architect or engineer or ordinary consumer of lumber who has an understanding of lumber grades or species necessary to make his purchases to the greatest economy and advantage is rare. Ordinarily, he specifies his own grades or takes what he can get. Dissatisfaction and uncertainty react to the advantage of the substitute.

Adherence in the lumber industry to manufacturing specifications as to dimensions is a matter of considerable variation between different periods, between different mills in the same region cutting the same species, and between different regions and species. For many purposes such variations may be unimportant. For others, in which exact compliance with original designs is a necessity, it undoubtedly creates dissatisfaction. An evidence of such dissatisfaction are the resolutions passed in December, 1915, by the Illinois Chapter of the American Institute of Architects, urging that the Government be given jurisdiction over lumber, that penalties be established for the failure of manufacturers or dealers to furnish the full sizes required by specifications, that the Government take steps to establish rational

unit stresses for various grades and species, and that a movement be started to examine and report upon the grading rules of the lumber associations.

COMPARATIVE COST.

Cost, equally with service or utility, may determine the ultimate use of competing materials. Satisfactory comparative costs of final structures made of different materials are difficult to obtain. Wholesale prices of these materials are much simpler and will answer the purpose of this discussion practically as well. The relative prices, or index numbers, shown in figures 1 and 2 for lumber, brick, bar iron, portland cement, and "all commodities," for 1890 to 1914 or

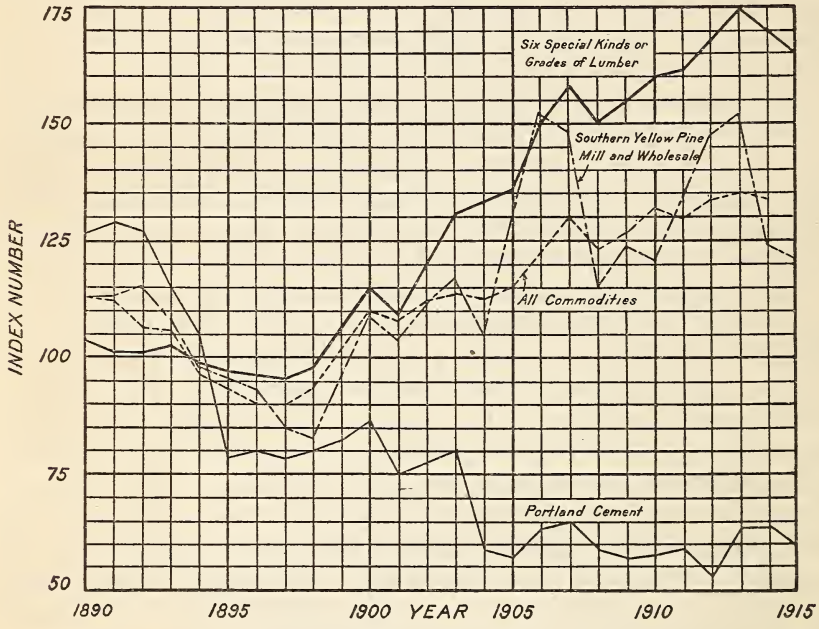

FIG. 1.—Index numbers of wholesale prices; lumber, Portland cement, all commodities.

1915, inclusive, are, with the exception of the yellow-pine mill and wholesale prices, based largely upon data taken from the publications of the Bureau of Labor Statistics, Department of Labor.

Some explanation of these curves appears necessary before discussing the conclusions to be drawn from them. The six special grades or kinds of lumber are hemlock, poplar, spruce, yellow pine, maple, and white oak. The Bureau of Labor Statistics prices, on which the curve for these species is based, are taken from quotations in the New York Lumber Trade Journal. Base prices are used for hemlock and spruce, and prices for one or two selected grades of poplar, yellow pine, maple, and oak. The average mill and wholesale price of southern pine is based upon mill prices, which, as will

be shown later, are also largely wholesale prices. They were obtained by the Forest Service. The brick is common red domestic, the bar iron, "best refined" from the Philadelphia market; and the Portland cement domestic. The "all commodities" curve represents the unweighted arithmetical average index price of the 252 commodities on which the Bureau of Labor Statistics secured data. It indicates the actual trend of wholesale prices in the United States. Prices are made comparable by indexes. An average of the prices of any commodity from 1890 to 1899 represents the normal price of 100 per cent in the commodity curve. The price for each year is then calculated as a percentage of the normal price and so expressed. For the normal price of cement, the Bureau of Labor Statistics data for 1895–1899 were supplemented by prices constructed from United States Geological

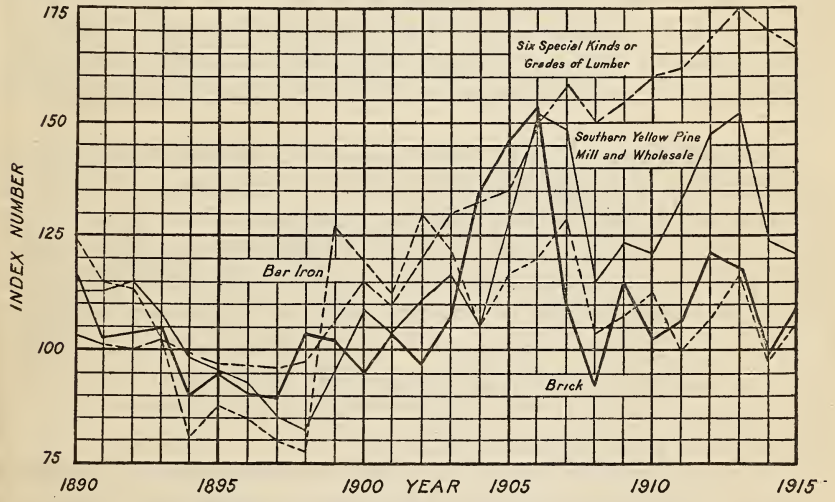

FIG. 2.—Index numbers of wholesale prices; lumber, bar iron, brick.

Survey statistics. Prices of structural steel shapes comparable with the others used in figures 1 and 2 were not available, and those for bar iron are given as representing the best substitute. Prices could not be obtained for clay building tile, for which statistics of production are given later, but are understood to have varied only slightly in the last two decades.

Neither of the lumber curves presents an entirely fair picture of the wholesale price situation. That for the six kinds of lumber is made up largely of species and grades in which prices for various reasons have been above the average and the volume of material sold comparatively small. The average mill and wholesale price for yellow pine is a mill price which includes a large number of sales direct to retailers. It includes selling costs, but is not a truly representative wholesale price because it does not include freight rates from the

mill to the retail yard. The yellow-pine prices are representative of material which forms the great bulk of the lumber cut.

The true wholesale lumber price curve falls between the two given. A general though not regular increase in lumber prices is shown for the 25-year period covered. A broad study of the situation indicates that the increase in lumber prices until 1907 was more rapid than the average for all commodities; since then the increase, if any, has been less rapid than the average. For the period shown, the general tendency has been toward increasing prices for lumber and decreasing prices for its competitors. Exact percentages can not be given in the case of lumber; but between 1890 and 1915 common red domestic-brick prices fell 7 per cent, bar-iron prices 15 per cent, and cement prices 54 per cent. A more or less regular increase in lumber prices and a drop in cement prices of 54 per cent during the same period, coincident with the development of the cement industry, are indicative of one set of economic conditions which have made possible the very active competition of cement and its products with wood.

Incidentally, the curve of brick prices is of interest when studied in connection with figure 5 showing the consumption of building brick in the United States. With the exception of the peak during the years from 1904 to 1906, the price of brick has been very steady, whereas the consumption has varied widely. The point of highest price corresponds to one of the two points of greatest production, and the other point of maximum output corresponds with a minor peak in the price curve during the unusually prosperous year of 1909. There appears to be a direct relation between exceptional volume of demand and marked increases in price.

The general tendency of the economic and other factors discussed is apparently to decrease the use of lumber in building and construction. The bulk of new construction involving the use of lumber has been completed in many of the agricultural regions of the United States. The pronounced move of population from country to city now taking place apparently tends to favor substitutes at the expense of lumber. The complex grading situation, a somewhat variable adherence to manufacturing standards, and lack of exact knowledge of its properties have handicapped lumber in its competition with substitutes. The prices for lumber have risen while those of its principal competitors have remained stationary or decreased. The statistics which follow lead to the same conclusion.

Statistics of Production, Consumption, and Substitution.

Since data showing directly the relative use of different materials in the building trade are unavailable, it has been necessary to use as nearly related statistics as could be obtained which obviously can

show the situation only in a broad way. These statistics fall into four classes:

1. The production or consumption of the principal building materials, lumber, cement, steel, brick, and clay building products other than brick.
2. Building permits.
3. Estimates of substitution by retail lumber dealers.
4. The replacement of wood in certain special uses; specifically, interior house trimming, bridges, crossties, and mine props.

PRODUCTION AND CONSUMPTION.

The total estimated lumber consumption in the United States is shown in figure 3. This is one of the best indexes available of the changing use of wood in building and construction. Curves giving the number of mills reporting and their reported cut of lumber are shown to indicate graphically as far as possible the basis for the estimates of total consumption. These estimates, except that for

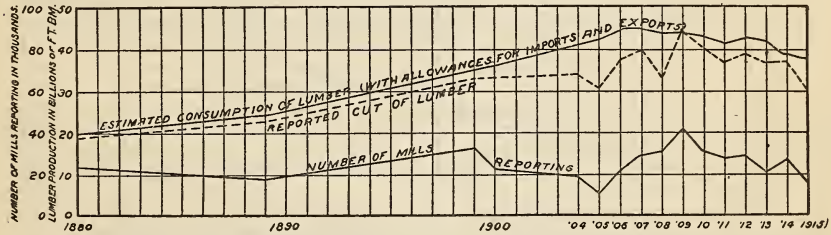
NUMBER OF MILLS REPORTING IN THOUSANDS
LUMBER PRODUCTION IN BILLIONS B.M. FT.
ESTIMATED CONSUMPTION OF LUMBER WITH ALLOWANCES FOR IMPORTS AND EXPORTS
REPORTED CUT OF LUMBER
NUMBER OF MILLS REPORTING
1880
1890
1900
'04 '05 '06 '07 '08 '09 '10 '11 '12 '13 '14 1915

FIG. 3.—Lumber consumption in the United States and number of mills reporting production.

1909, for which a very complete census was taken, represent the consensus of opinion of a number of men familiar with the records of lumber cut for a number of years and the conditions in the industry. Allowances were made for exports and imports. The number of mills reporting varies to a considerable degree with the character of the census and is not necessarily an indication of the number of mills in operation during any year. Ordinarily, however, the bulk of the mills not reporting were of small capacity and did not materially influence the total cut.

As already stated, the lumber consumed in general building and construction during the year 1915 is estimated at 27 billion board feet, or 71 per cent of the total lumber consumption. Assuming that approximately the same percentage holds for other years, about 32 billion board feet were used in general building and construction in 1907, probably the year of maximum lumber production and use in the United States. On this basis the falling off in the amount of lumber used in building construction since 1907 exceeds 15 per cent This indication of the substitution which has taken place is inexact to the extent that decreased consumption is due to other causes than

the replacement of wood by other materials. The decline in lumber consumption since 1907 has been remarkably uniform. Per-capita consumption, as shown in figure 4, fell from 516 board feet in 1906 to 375 in 1915. The curve falls more rapidly than that of total consumption because of the rapid increase in population.

The consumption of building brick in the United States as shown in figure 5 has apparently fallen off about 27 per cent since 1909. The total is made up of common and front clay brick, common front and finish sand-lime brick, and sand-lime blocks. Sand-lime brick represent about 2 per cent of the total consumption.

Evening out violent fluctuations, the consumption of iron and steel structural shapes, practically all of which are eventually used in buildings and bridges, has on the whole, as shown in figure 6, increased rapidly from 1898 to 1913. This increase was 285 per cent to 1913, and 174 per cent to 1914, an off year. The consumption of steel

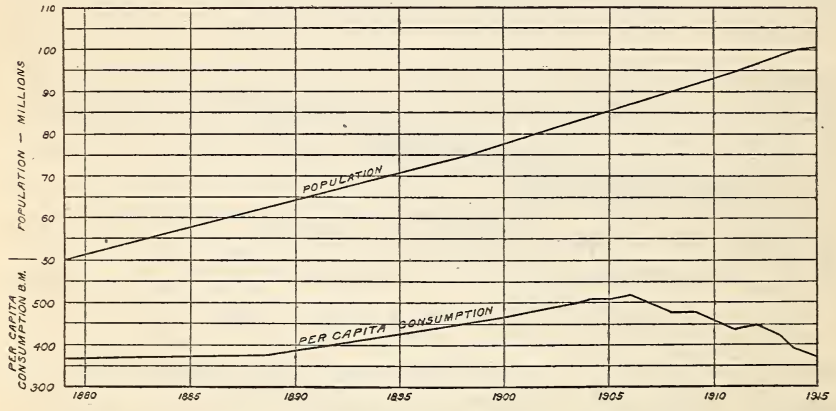

FIG. 4.—Population and per capita lumber consumption of the United States.

during 1906–7, the years of maximum lumber consumption, and 1914 are nearly identical, in spite of the fact that the general trend for steel is upward, while it is downward for lumber.

Natural cement was still popular 30 to 35 years ago when the Portland-cement industry was in its infancy. Most of the present production in the United States, however, as is shown in figure 7, is Portland cement. Between 1907 and 1915, while the total lumber consumption fell off approximately 15 per cent, cement consumption increased 48 per cent. The cement-consumption curve shows a rapid and practically unbroken increase, and in this respect differs from the curves for all of the other principal construction materials.

The value of various clay building materials produced in the United States is shown in figure 8. "Tile not drain" includes floor tile, wall tile, roofing tile, and faience, or art tile. The proportionate output of the various products is indicated for the year 1913 by the following valuations: Floor tile, $2,483,082; wall tile, $1,763,992; roofing tile,

$1,130,286; faience, $731,820. Evening off rather violent fluctuations, production of all the clay products has increased rapidly since

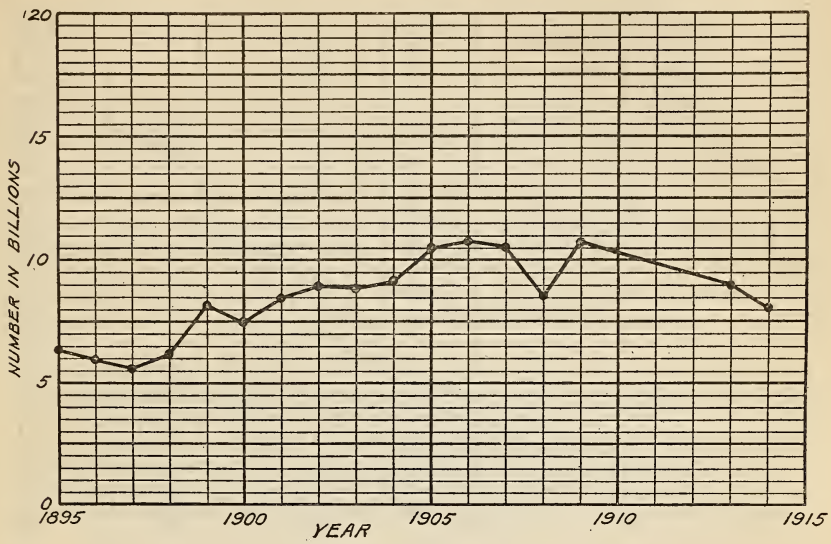

FIG. 5.—Consumption of building brick in the United States.

1899. From 1907 to 1915 the general increase has been about 20 per cent, while lumber consumption has fallen off more than 15 per cent.

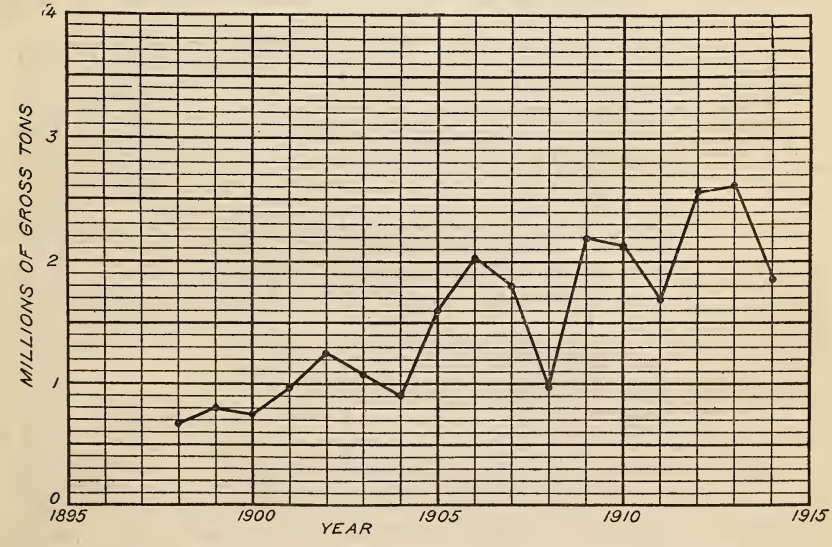

FIG. 6.—Consumption of iron and steel structural shapes in the United States.

Further evidence on the relative consumption of iron and steel shapes and lumber in building construction is presented in figure 9,

showing the consumption of steel shapes and cut wire nails on a basis made comparable by indexes. The consumption in 1914 has been

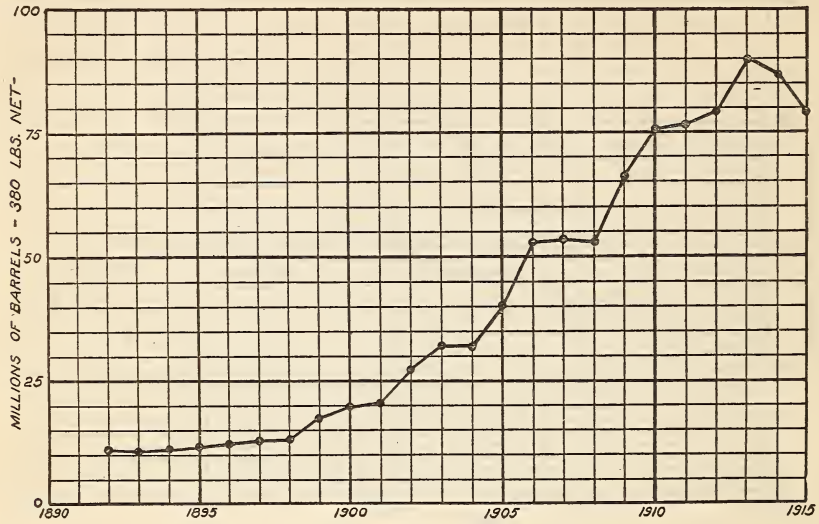

FIG. 7.—Consumption of natural and Portland cement in the United States.

taken as the base, or 100 per cent, for both curves. Percentages for other years are then determined by comparing the consumption during the year with that of 1914. If the consumption of nails

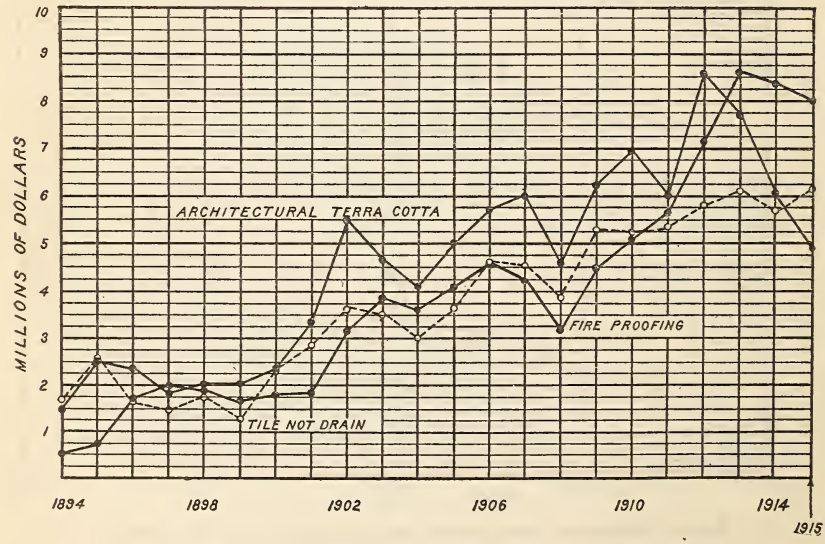

FIG. 8.—Value of production of clay building materials in the United States.

is a good general indication of the use of lumber in building and construction, as is sometimes assumed, the curve indicates that there

was a steady increase from 1898 to 1909, and since that time a falling off amounting to approximately 20 per cent. The use of structural shapes, although erratic, has in general increased rapidly.

Exact data on the consumption of the various competing materials comparable with the 27 billion feet of lumber used in general building and construction are not available. Innumerable variations in the forms of use make the collection of such data practically impossible; and in many forms of construction it is impossible to draw an exact line where substitution begins and ceases, although the extremes may be clear. This holds true, for instance, in railway and highway bridges and in buildings. The total production or consumption curves which have been given, however, undoubtedly indicate broad tendencies toward the substitution of other materials for wood in

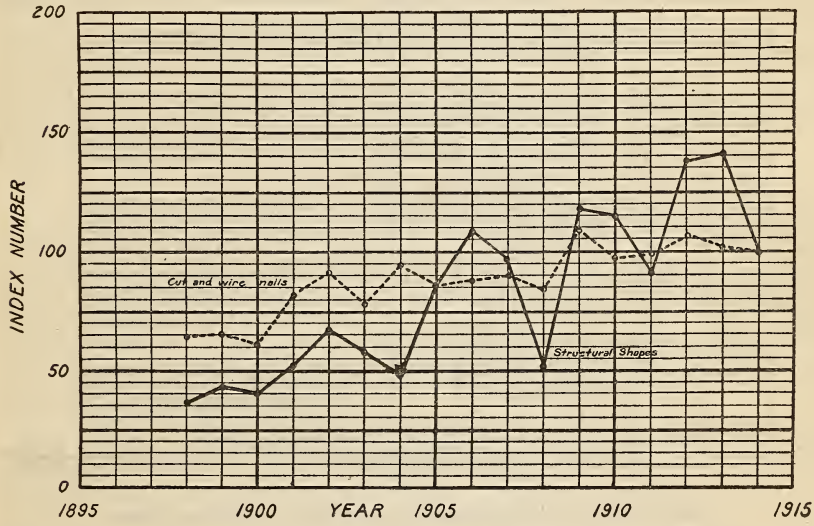

FIG. 9.—Index numbers of consumption of cut and wire nails and structural shapes in the United States.

building and construction. These curves show that, with the exception of brick, the consumption or production of lumber's principal competitors has, eliminating minor fluctuations, increased steadily. Since 1906–7, when the lumber cut reached its peak, this increase probably has amounted to 45 per cent in the case of structural steel shapes, to 48 per cent in the case of cement, and to 20 per cent for clay products, while lumber has dropped off more than 15 per cent.

The peaks and depressions in the various production curves are an excellent index of the general financial conditions in the country during the period covered. Thus in 1908 all of the materials, except cement, suffered a sharp decline and cement showed a small rate of increase. Since 1893 the production of cement has fallen off only in 1914 and 1915, whereas all of the other materials, notably steel, have shown sharp declines from time to time.

BUILDING PERMITS.

The second class of statistical data bearing on substitution is based upon the building permits issued by various cities. From data published by the United States Geological Survey in its annual report on the mineral resources of the United States, curves have been constructed, figure 10, showing the value of the building permits issued in 20 cities, by classes. The classes are wood, brick, stone, concrete, and all other not wood. The last includes steel-skeleton construction. Veneer and stucco buildings are included under wood. An estimate of the extent to which stucco has replaced wooden siding has, however, been obtained in another way and is given later. The 20 cities are: Atlanta, Ga.; Boston, Mass.; Cleveland, Ohio; Grand Rapids, Mich.; Hartford, Conn.; Indianapolis, Ind.; Kansas City, Mo.; Los Angeles, Cal.; Louisville, Ky.; Lowell, Mass.; Milwaukee, Wis.; New York,

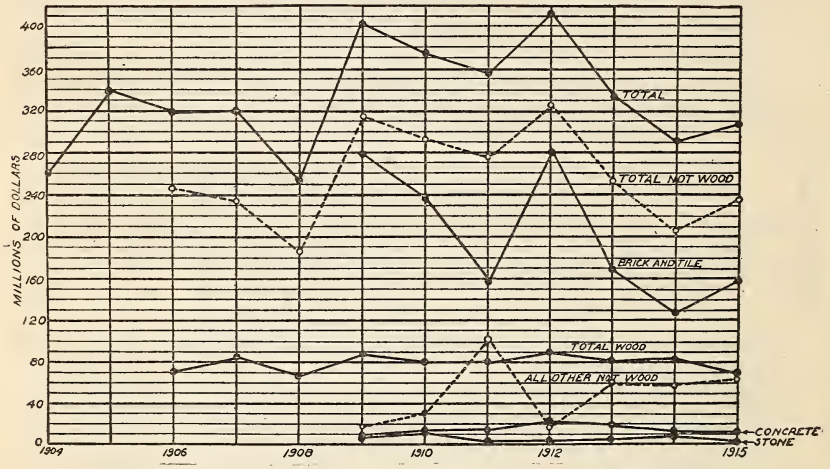

FIG. 10.—Value of building permits issued in 20 cities of the United States.

N. Y.; Philadelphia, Pa.; Richmond, Va.; Rochester, N. Y.; San Francisco, Cal.; Scranton, Pa.; Seattle, Wash.; Syracuse, N. Y.; and Washington, D. C. With a few minor exceptions, the data from all of these cities are exactly comparable, and these exceptions have practically no effect upon the final curves. Unfortunately, it is not possible to subdivide the "not-wood" curve into its components for the years 1906–1908, inclusive.

The depression in all of the curves for 1908 is very marked. It corresponds to similar depressions in the building-material curves. The lesser depression in 1911 is also reflected in practically all classes of building permits. Lumber, so far as town construction is concerned, is shown to be the most stable of all the building materials. General financial conditions are first reflected in the permits for brick and tile buildings and last in wooden buildings. In other words, the construction of wooden buildings in towns tends to follow

the even tenor of its way irrespective of panics and financial depressions. This is undoubtedly due to the larger proportion of small residences built of wood, the demand for which is less dependent upon the financial barometer. The total-wood curve has been practically uniform since 1906–7. This curve does not, however, indicate the substitution of stucco for wooden siding, which may amount to as much as 13 per cent; and also does not indicate the amounts absorbed by the general increase in labor costs in the building trades, which account for from 5 to 15 per cent of the value of the 1913 permits. These two factors taken together indicate, therefore, that the use of wood in building construction in the 20 cities listed has fallen off. On the other hand, the total building curve for the 20 cities, while erratic, increased on the whole nearly 30 per cent between 1904 and 1913, although the latter was an off year; and the prices of the principal structural materials other than wood remained stationary or decreased. The difference between these curves can be regarded as indicating substitution for lumber only in part because of the increasing use of competing materials for purposes for which wood is not suitable.

RETAIL LUMBER DEALERS' ESTIMATES OF THE AMOUNT OF SUBSTITUTION.

The third class of statistical data consists of estimates of the extent of substitution for lumber and other wood products secured from retail lumber dealers. In 1910, the Forest Service sent the following inquiry to 3,000 representative lumber dealers in Ohio, Indiana, Illinois, Missouri, Kansas, Oklahoma, Nebraska, Iowa, North Dakota, and South Dakota:

> How much do you estimate the use of cement, concrete, tile, prepared roofings, and other substitutes for lumber and shingles has lessened the demand in your locality in the last three years for the following classes of material? Please base your replies as far as possible upon your experience as a dealer in these commodities. What in your opinion are the prospects for a further increase in the use of substitutes?

The wooden products listed were dimension stuff, sheathing, siding, finishing lumber, flooring, common lumber, fencing, shingles, lath, pickets, and fence posts. The dealers were also asked to specify whether they supplied chiefly city or town and country trade. The estimates furnished in 1,198 replies are summarized in Table 1.

TABLE 1.—*Substitution for wood, 1907–1909, as estimated by retail lumber dealers.*

Material:	Per cent of decrease in sales due to substitutes.	Material—Continued.	Per cent of decrease in sales due to substitutes.
Dimension stuff	5.4	Common lumber	5.3
Sheathing	2.4	Fencing	13.7
Siding	4.1	Shingles	16.2
Finish	.9	Lath	3.0
Flooring	6.0	Pickets	9.4
Fence posts	3.7		

This indicates that substitution was most active in the case of fencing and shingles, amounting to 13.7 and 16.2 per cent, respectively, and least in the case of lath, 3 per cent, sheathing, 2.4 per cent, and interior finish, 0.9 per cent. A rapid increase in the use of nearly all substitutes was predicted. The reports from Illinois were divided into two groups to determine the relative extent of substitution in cities and in town and rural markets.

TABLE 2.—*Comparative substitution in city and country markets, 1907–1909, estimated by retail lumber dealers.*

Material.	City (27 reports).	Town and country (316 reports).	Material.	City (27 reports).	Town and country (316 reports).
	Per cent.	*Per cent.*		*Per cent.*	*Per cent.*
Dimensions	7.89	6.24	Fencing	12.96	17.88
Sheathing	5.26	2.27	Shingles	26.67	19.65
Siding	9.37	4.71	Lath	4.19	2.85
Finish	1.52	1.14	Pickets	21.70	12.06
Flooring	6.37	7.22	Fence posts	10.10	4.00
Common lumber	6.59	7.07			

The effect of building regulations in cities is reflected in the 7 per cent greater decrease in the use of wooden shingles and, to a lesser extent, in the decreased use of dimension stuff, sheathing, and siding. Tables 1 and 2 show the changes taking place in only three years and do not include substitutions prior to 1907.

To bring these data up to date, schedules were sent to representative retailers in the same territory requesting estimates on the extent to which substitutes have replaced various lumber products since 1910. Three hundred and thirty-seven of the reports received could be summarized; and Table 3, showing the decreases in the use of wood from 1907 to 1914, inclusive, has been prepared by combining these reports with those previously discussed:

TABLE 3.—*Substitution for wood products, 1907–1914, estimated by retail lumber dealers.*

Material:	Per cent of estimated decrease in sales due to substitution.	Material—continued.	Per cent of estimated decrease in sales due to substitution.
Dimension stuff	13.4	Fence posts	11.9
Siding	15.0	Fencing	42.3
Finish	3.0	Shingles	35.0
Flooring	14.1		

These estimates indicate that in a part of the Middle West the decreases in the sale of lumber at retail yards, from 1907 to 1914, inclusive, were 3 per cent for interior finish, 13.4 per cent for dimension stuff, 14.1 per cent for flooring, and 15 per cent for siding, the average probably being in the neighborhood of 13 per cent.

HOUSE TRIMMING AND OTHER SPECIAL PRODUCTS.

The fourth class of statistics deals with the production of metal trim for interiors, sash, doors, and the like, and the extent to which it is replacing lumber, and with substitution in bridge construction and for ties and mine timbers.

Metal trim.—Metal trim, the use of which has been increasing rapidly, competes directly with planing-mill products. Its principal use is in fireproof construction, especially within the fire limits of cities but it is also used to a large extent in factories, where exceptionally large amounts of light are secured by great areas of steel sash. Table 4, which includes iron and steel doors and shutters, elevator and vault doors, automatic mine doors, rolling steel shutters, metal and metal-covered window frames, sash, and trim, is based upon census data.

TABLE 4.—*Metal-trim production.*

Year.	Number of firms reporting.	Value of product.	Year.	Number of firms. reporting.	Value of product.
1889	7	$88,515	1904	24	$1,477,235
1899	13	319,629	1909	29	3,005,685

The value of metal-trim products increased from $88,515 to $3,005,685, or 3,290 per cent, in the 20 years ending 1909. In con-

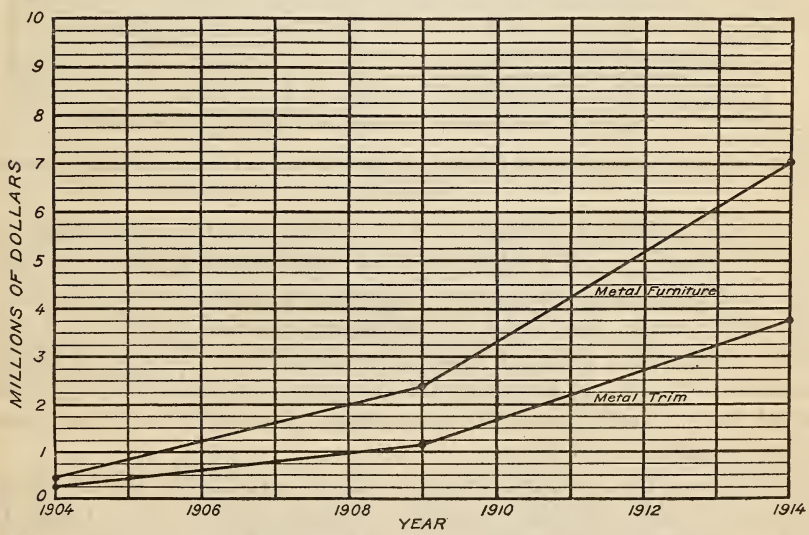

FIG. 11.—Value of metal trim and furniture produced in the United States.

nection with a census of metal-furniture production to be discussed later, the Forest Service also conducted a partial census of metal-trim production in 1905, 1909, and 1914. Reports from 18 manufacturers on the production of metal doors, door frames, window sash, window frames, moldings, base, and other trim are summarized in figure 11.

The increase in value in the output of these identical concerns during the 10 years is 1,360 per cent. The data do not include the production of new concerns.

The increase in production between 1909 and 1914 as shown by the Forest Service census was 240 per cent. The application of one-half of this rate to the census figure of total production in 1909, $3,005,685, indicates a total production in 1914 in excess of $6,500,000. The extent of substitution for lumber was estimated by assuming a value of $125 per ton for the metal products and further that each ton replaces 1,000 board feet of wood. Fifty million board feet annually probably represents the present substitution conservatively.

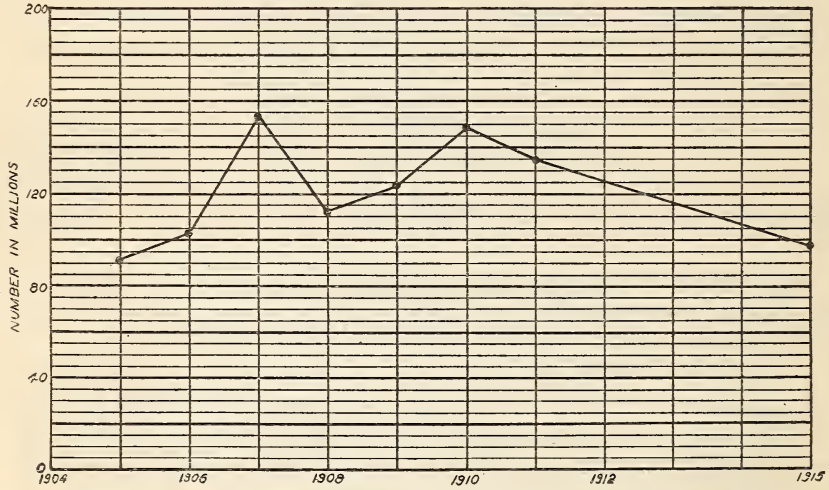

FIG. 12.—Crossties reported purchased by steam and electric roads in the United States (steam roads only in 1905).

Bridges, culverts, and trestles.—It is well known that practically all large and many small bridges are now constructed of steel and concrete and that the use of lumber, except for preliminary construction, temporary work, and forms, is restricted to small bridges and culverts. Even here it is not without competition. The use of bridge and trestle timbers by the railroads alone probably reaches 850,000,000 board feet annually, and the percentage of substitution is unquestionably large.

Crossties.—The wooden crosstie stands practically alone in its particular field. Though countless attempts have been made to find a satisfactory substitute, not one has yet been successful. It is possible to make ties of other material, and under certain conditions it may be economical to use them, but all the data available point to the general superiority of the wooden tie.

The wooden ties reported purchased by the steam and electric railroads in the United States, as shown in figure 12, represent approximately the demands of the railroads from 1905 to 1915, as influenced by general financial conditions to which railroad companies in their purchases seem to be particularly sensitive. The peak was reached in 1907 at 153,699,620 ties.

Exact data are not available upon the purchase of steel and concrete ties, but from reports on the condition of substitute ties in various roads in the proceedings of the American Railway Engineering Association it is estimated that about 2,000,000 steel ties are now in service. A large portion of these is found in the tracks of two roads, the Bessemer and Lake Erie and the Union. Probably not more than 400,000 cement ties are now in use. The total of 2,400,000 substitute ties is insignificant when compared with the total of wooden ties, which is in the neighborhood of 850,000,000.

The average life of wooden ties is about seven years. Substitute ties therefore replace annually about one-seventh of their total of 2,400,000, or 343,000 wooden ties. The average tie contains about 32 board feet. The total annual replacement of wooden ties is therefore about 11,000,000 feet. Approximately 75 per cent of all ties are hewn, so that the substitution for sawed ties, or lumber, is negligible, amounting to only about 2,500,000 board feet a year.

Mine timbers.—Although no specific data are available on the extent of the replacement of wooden mine timbers by other materials, it is known to be comparatively slight, probably less than one-tenth of 1 per cent, and is confined mostly to main shafts and headworks.

The mines are important consumers of wood, their requirements for 1905 being reported in Forest Service Circular 49 at 165,535,900 cubic feet of round and 435,944,000 board feet of sawed timber, or a total of more than 200,000,000 cubic feet. Much of the round timber was too small for manufacture into lumber. Its total volume was, however, equivalent to 1,986,430,000 board feet, and the grand total in board feet was 2,422,374,800. The above report, covering more than 5,000 mines, probably represents over 90 per cent of the total timber consumption in mines during that year

PARTIAL SUBSTITUTION AND INCREASED USE.

Partial substitution and actual increases in the consumption of lumber, in connection with the use of materials which for many purposes are active competitors of wood, must be considered before general conclusions concerning the amount of substitution in general building and construction can be drawn. No general data are available on either point. The use of lumber forms for the construction of cement floors illustrates the first. Examples of this character are

frequently cited to show that supposed substitution has not necessarily decreased the use of lumber or to any great extent prevented the normal increase in its use. The following illustration, even though it be heavily discounted, clearly indicates decreased use. A heavy warehouse floor with a 3-inch subfloor, ¾-inch top flooring, 8 by 16 inch joists spaced 5 feet, 18 by 24 inch stringers spaced 20 feet, 12 by 12 inch columns spaced 20 feet, and 12-foot ceilings would require about 8 feet of lumber per square foot of floor space. The use of lumber for forms in constructing concrete floors varies widely, but would probably average in a building of the above sort less than 4 feet board measure per square foot of floor. Since forms could probably be used five times on the average, the heavy warehouse floor requires ten times as much wood as the cement floor; lighter wooden floors would require correspondingly less, and on the other hand use up less lumber in forms.

This instance is typical of buildings and other structures in which concrete and wood compete on the same footing, and in which the concrete used is in effect a substitute for lumber only in part because of the consumption of more or less wood in making forms. With the increase in height of office buildings, lumber labors under an increasing disadvantage, until in extreme cases its use is limited to finish or surface flooring or is eliminated altogether. Where its place is taken by cement, it remains a factor for structural forms, as already indicated.

There are many uses of concrete in which it can not be considered as a substitute for wood at all but in which it is a competitor with tile, brick, masonry, or steel. The most important of these are dams, waterworks of all kinds, tubes, tunnels, large bridges, canals and locks, foundations, retaining and sea walls, dry docks, tall buildings, and other related structures. Forms and other temporary structures in these types of construction represent a new use of wood. Lumber does not even, however, have a monopoly of cement forms, which now have a substitute of their own. Steel forms may be purchased or rented for almost any kind of concrete structure from a curb to a water-supply system for a large city. There are no accurate data on hand to show the extent of the use of steel forms, but general observation indicates its steady growth for certain classes of construction. Thus for round columns steel forms are used by many contractors who do not employ them for any other purpose.

In arriving at a conclusion regarding the extent to which concrete and other materials are replacing lumber in general building and construction, the amount of lumber used in forms and temporary work must be taken into account. Data on its aggregate amount are not available, but it is undoubtedly small as compared with the total displacement of lumber.

SUMMARY.

It will be evident from the preceding that exact data on the total substitution for lumber in general building and construction can not be obtained. At the best its extent can only be estimated after weighing all of the available, and to some extent conflicting, data. Both economic considerations and statistics point to the same conclusion—substitution for lumber in general building and construction is already large and is increasing.

The principal factors responsible for this situation are the completion of the bulk of construction in the great agricultural regions; the rapid increase of urban as compared with rural population, which has been accompanied by building legislation and other developments which tend to favor substitutes; general tendencies toward changes in construction which rarely favor lumber; increase in lumber prices while those of its competitors have remained stationary or fallen off; and, finally, the greater amount and variety of special service which has been rendered to consumers by the substitute industries.

Lumber consumption in the United States reached its maximum in 1907 and has since fallen off approximately 15 per cent. During the same period the use of lumber in general building and construction has probably fallen from 32 to 27 billion feet, or about 5 billion feet. Brick is the only competing material whose consumption has fallen off; the percentage since 1907 may even exceed that of lumber. Though the consumption of iron and steel structural shapes was nearly identical in 1906–7 and in 1914, an off year, the general trend of the steel curve is upward, while that of lumber is downward. The general increase in steel consumption was probably about 45 per cent between 1907 and 1914, and the rise in the curve from 1900 to 1907 was similar to that from 1907 to the present. The increase in cement consumption from 1907 to 1915 is 48 per cent and that from 1900, 290 per cent. The increased consumption of clay building products during the same periods was 20 per cent and 170 per cent, respectively. The use of nails, which reached its highest point in 1909, indicates that lumber consumption in building construction has since fallen off 20 per cent. Building permits in 20 cities, considering the increase in labor costs and the substitution of stucco for wooden siding, indicate a falling off in the construction of wooden buildings. At the best the wooden building is no more than holding its own, while the total building curve is rising. Retail lumber dealers estimate the decrease in sales of lumber for construction purposes, due to substitution, to have been in the neighborhood of 13 per cent between 1907 and 1914 alone. It is probable that metal trim is now replacing at least 50,000,000 board feet of planing-mill products, and its production is increasing rapidly. The percentage of substitution in the construction of bridges is probably very large. On the other hand,

substitutes for sawed ties are very limited, not exceeding 2,500,000 board feet annually, and for mine timbers are insignificant.

The consumption of lumber in forms and other temporary work is increased to some extent by the use of cement and other materials for new types of structures for which wood is not suitable; and further, a certain amount of wood is used in connection with the actual replacement of itself by cement and other competitors as the main building material. These factors offset in part the percentages of displacement above indicated. Considering all these factors, a substitution equivalent to 15 per cent of the present consumption of lumber in general building and construction, or about 4,050,000,000 board feet annually, seems conservative. This figure is little more than four-fifths of the probable decrease in lumber consumption in general building and construction since 1907, contains no allowance for the logical increase in demand which has probably been absorbed by substitutes, and makes no allowance for substitution prior to 1907. If increased by 1,000,000,000 feet, it would still probably be within the actual substitution which has taken place.

Data for the entire country on the building situation as a whole are unavailable. There are obvious difficulties in reducing to a common structural unit, as a basis for comparison, such different materials as lumber, cement, structural steel, and brick and other clay building products; and this is made still more difficult by the innumerable forms of use in building construction. An approximation of the general situation may, however, be obtained from a consideration of the total values of the principal construction materials, as shown in figure 13. Lumber values were obtained by applying a 10-year average mill price, $14.74, to the total estimated production as given in figure 3; cement values, by using a 20-year, 1895–1914, average mill price of $1.72 obtained from the Bureau of Labor Statistics,[1] with the production of cement shown in figure 7; structural steel values, by using the Bureau of Census mill value of $33 averaged for 1909, 1904, and 1899, with the consumption data shown in figure 6; and building-brick values by using a 17-year average price of $6.05 per 1,000 on red brick, taken from Bulletin 181, Bureau of Labor Statistics. For other clay building products it has been necessary to use the total value of the output as reported annually. While not directly comparable with the other curves this can have little influence on the results shown.

The percentage of the various materials which compete in general building and construction undoubtedly varies somewhat between materials and from year to year, so that the curves are not exactly comparable. It is believed, however, that the curves clearly indi-

[1] Bulletin 181.

cate a rapid and fairly regular increase in building and construction as a whole up to 1913; and further, that the increased consumption of building materials other than lumber was more than enough, after 1907, to offset the decline in lumber production and continue the increase in the total amount of building. In short, building and construction in the country seem to be increasing despite the fact that lumber, still by far the leading construction material in the value of its output, has been falling off since 1907. Similar tendencies are also indicated by figure 10.

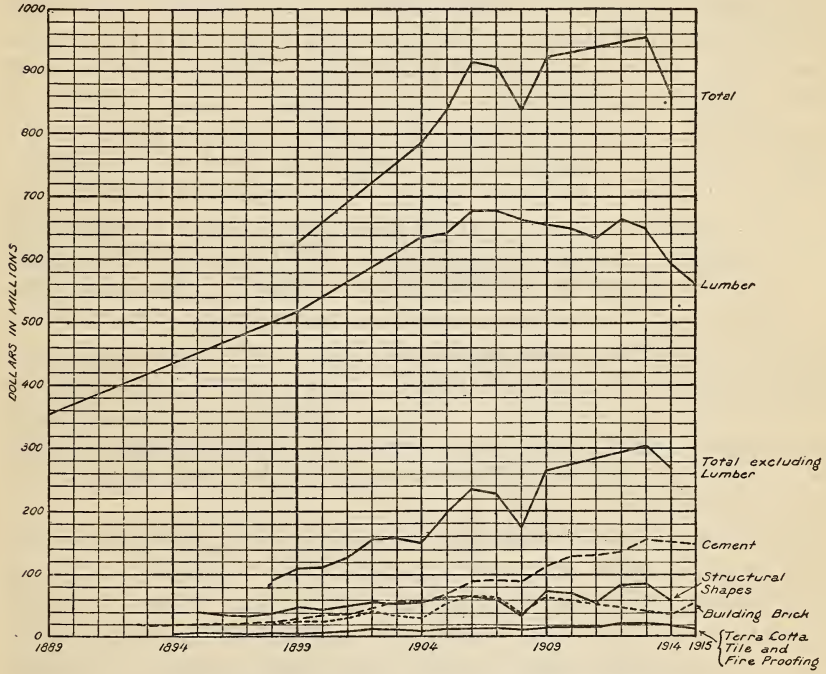

FIG. 13.—Values of principal materials used in building construction.

While the wooden tie will probably hold its own against substitutes for a long time, the annual consumption of ties will probably fall off as larger percentages are treated against decay and properly protected by tie plates and improved fastenings. There is apparently no reason to expect an increased use of substitutes in mining structures. The percentage of timber used for these purposes, compared with the total of 27,000,000,000 board feet consumed in building and construction is, however, small. The economic and other factors which are responsible for the substitution in other classes of building and construction may be expected to be as active in the future as in the past, or even more active, unless counteracted by forces not now in evidence.

FENCING.

The extent to which substitutes have replaced wooden fencing is difficult to realize until one compares the fences of 20 years ago, when barbed and woven wire fencing were coming into use with those of today. At that time the manufacture of wooden fencing was a flourishing industry. Garden and yard fences were made of various kinds of pickets; chicken and barnyard fences, of lath held in place by strands of woven wire, or of boards; and the most popular types of field and pasture fences were constructed of rails, stone, or boards.

A number of factors are responsible for the changed conditions. One of the most important is the decreasing supply in many regions of available material suitable for rail fences. The fence rail is essentially a pioneer product and a logical corollary of the clearing of forested land. The worm fence wastes nearly twice as much ground as the wire or board fence. The increase in land values, the increasing costs of farm labor, and the growing realization that the rail fence row forms a refuge for weeds and insects created a demand for other materials. Before the wire fence was introduced this demand was supplied mainly by the board fence. Finally, the demand for wire fencing of various sorts has been wonderfully stimulated by ease of construction, neat appearance, low initial cost, and small cost of upkeep. It is a substitute for the stone fence and hedge as well as for the wooden fence. In some regions, such as the western stock ranges, wire fencing is the only kind practicable and the only one ever in general use. To this extent it has not replaced the wooden fence.

The substitution of cement and, to a lesser extent, steel for wooden fence posts is often largely a question of the available supply of suitable material at reasonable cost. Convenience in getting to the place of use and in fence construction and greater service or durability may in other cases be the controlling factors. Substitute posts in practically all cases have gained ground in spite of higher initial costs. As in the case of many substitutes, a special attempt has been made by the cement industry to meet the needs of the farmer for fence posts. They may be purchased ready-made from plants throughout the country, or forms and necessary reinforcements may be secured from firms which specialize in these materials, or the farmer is shown how to make his own forms and cement mixtures. In general, the amount of fencing other than for farms is small, and ordinarily the selection of the character of fencing or fence posts to be employed is based not only upon the supply of raw material, the labor available and its costs, land values, and the purpose of the fence, but also upon the feasibility of actual cash outlays for outside products.

The extent of substitution for wooden fencing and fence posts varies materially in different sections of the United States with varying local conditions. The best available statistics on the present situation in any region are contained in United States Department of Agriculture Bulletin 321,[1] which also is the source of other information given in this section. These statistics were secured by a farm canvass in North Dakota, South Dakota, Nebraska, Kansas, Minnesota, Iowa, Missouri, Wisconsin, Illinois, Michigan, Indiana, and Ohio. The total number of rods of each type of fence in the area studied and the percentage which each forms of the total were prepared from an abstract of the original data secured for Bulletin 321 and are shown in Table 5.

TABLE 5.—*Proportion of various types of fence in the North Central States.*

Kind of fence.	Length.	Proportion.	Kind of fence.	Length.	Proportion.
	Rods.	*Per cent.*		*Rods.*	*Per cent.*
Wide woven wire	1,717,091	22.1	Hedge	341,797	4.4
Narrow woven wire with barbed wires	2,025,272	26.0	Types of wooden fencing	533,457	6.9
Barbed and smooth wire	3,147,649	40.5	Stone fence	13,362	.17

Various types of wire fence represent 88.6 per cent of the total in the area under consideration, while all types of wooden fencing represent only 6.9 per cent.

The census of 1910, the first reporting barbed wire separately, gives its production for 1909 at 323,565 tons and that of woven-wire fencing at 433,127 tons. Barbed-wire exports for 1909 were 79,309 tons, and woven-wire exports, which were not reported separately prior to 1912, are estimated at 5,750 tons. Neglecting imports, which are small, the annual consumption in the United States is approximately 660,633 tons of barbed and woven wire. This is largely a substitute for wooden fencing, including rails and lumber in various forms.

Data on the consumption of lumber for fencing when it was greatest are not available. Tables 1 and 3 show that between 1907–1909 and 1910–1914 the decrease in demand for fencing in the Middle West amounted to 13.7 per cent and 42.3 per cent, respectively, and that the use of wooden fence posts dropped off 3.7 and 11.9 per cent in the respective periods. Between 1907 and 1909 the consumption of wooden pickets decreased 9.4 per cent; but before this time substitution for the board fence had already taken place very largely. Because of the various methods used in making concrete posts, it is practically impossible to obtain even appromimate data on the number used annually. It is known, however, that the number of

[1] "Cost of Fencing Farms in the North Central States," by H. N. Humphrey.

manufacturers of reinforced concrete posts and of forms for casting them is increasing rapidly. It seems certain, therefore, that substitution for wooden posts is increasing.

It is estimated that five-sixths of the barbed and woven wire consumed in the United States in 1909 was substituted for wood. To determine the equivalent in wood of 550,000 tons of wire, it is assumed that 1 ton of wire replaced 6,000 board feet of wood. The total replacement thus amounts to approximately 3,300,000,000 board feet a year. Of this total it is estimated that roughly 30 per cent represents a substitution for sawed lumber, or 1,000,000,000 board feet.

Little data are available on the annual consumption of wooden posts in the United States. Unquestionably, it is several times greater than the consumption of railroad ties, which is reported in Forest Service publications as 135,000,000 during 1911. Circular 166 [1] estimated that 1,800,000,000 cubic feet of timber are used annually for poles, posts, and rails. Possibly one-third of this amount, or 600,000,000 cubic feet annually, is in the form of posts. This would be equivalent, roughly, to 2,500,000,000 board feet. A substitution of 10 per cent of steel and cement posts would displace 250,000,000 board feet of wood yearly, but probably not more than a tenth of the wood displaced is in the form of sawed lumber. No increase for this small amount is made in the total estimated substitution for lumber in the construction of fences. The aggregate yearly displacement of wood for this purpose is thus put at 3,550,000,000 board feet, and of lumber alone at 1,000,000,000 feet.

Barbed wire and woven wire have reduced the market for fencing lumber to a small percentage of that of 25 or 30 years ago. Although this market may not be reduced much further, there is no reason to believe that it will increase. Rail and stone fences will be replaced almost altogether by wire or other metal types. Practically the only place left for lumber seems to be in ornamental fences, town fences, and certain types of high, tight fences which surround farmyards, athletic fields, etc.

The demand for wooden fence posts has decreased much less than for fencing, although steel and especially reinforced concrete posts are being used in increasing quantities. There is apparently no ground for belief that this substitution will not be extended. The sawed post is a somewhat negligible factor. It will probably retain its place in ornamental and other special types of lumber fences indefinitely. The preservative treatment of wooden fence posts will, on the one hand, tend to reduce demand by increasing their durability, and on the other will increase their desirability in competition with substitute posts.

[1] "Timber Supply of the United States," by R. S. Kellogg, published by the Forest Service in 1909.

SIDEWALKS.

The wooden sidewalk, so common 25 years ago, is a thing of the past in most cities and in many small towns as well. There is probably no other use in which wood has disappeared so completely in so short a time. The Municipal Journal of February 3, 1916, published statistics which are reproduced in Table 6 upon the amount of sidewalk of various kinds laid in 542 cities in the United States in 1915:

TABLE 6.—*Sidewalk laid in 542 cities in 1915.*

Type.	Square yards.
Concrete	4,715,039
Tar concrete	124,392
Stone	94,237
Brick	61,626
Granolithic	12,684
Flagstone	5,611
Wood	4,614
Tar	3,997
Tile	1,955
Dressed granite	1,249
Artificial stone	500
Total	5,025,904

Wooden sidewalk totaled 4,614 square yards out of 5,025,904, or nine one-hundredths of 1 per cent.

Assuming that 10 per cent of the cement produced in 1914, 85,000,000 barrels in round numbers, has been substituted for wood in the construction of sidewalks, each 100 square feet of sidewalk taking 2.42 barrels of cement, and that each square foot of wooden sidewalk requires $1\frac{3}{4}$ board feet of lumber, the total substitution in this field of use amounts to approximately 600,000,000 board feet a year.

The wooden sidewalk has been almost entirely replaced by substitutes, and there is little prospect of its future use except in places where first cost is the main or only consideration.

ROOFING.

Roofing falls logically under general building and construction but is discussed separately because substitution involves wood in other forms than lumber. The "war of the substitutes" has probably been waged more intensively upon the wooden shingle than upon any other forest product. Both the agitation and the large replacement which has taken place are due in part to the peculiar fire hazard attached to roofing in urban construction. Ordinarily the first and most sweeping restrictions in building codes bear on the use of the wooden shingle. The effect is shown in Table 2, in which retail dealers estimate that substitution for shingles has been 7 per cent greater during three years in cities than in towns and rural districts.

The wooden shingle has undoubtedly labored under the same handicap as lumber as to variations in manufacture and seasoning and irregular grading practice, and has suffered accordingly in competition with substitutes which have complied uniformly with more

exacting specifications. There is also the question of appearance in the completed roof. Some of the substitute roofings have undoubtedly gained a preference through evenness of finish and the possibility of color variations which have recommended themselves to architects and owners. The advertising campaigns of substitute roofing industries have undoubtedly been stimulated by the necessity of replacing the wooden shingle to obtain any market at all, whereas in the case of most other substitutes for wood some markets have been available which do not involve substitution.

Finally, advantages have been gained by intensive investigation of industrial problems, in which the expenditures and undoubtedly the results obtained have in the case of substitute industries far exceeded those of the wooden shingle. In spite of the fact that the shingle is one of the cheapest of finished roofings, substitution has taken place at an increasingly rapid rate, while the production of shingles has barely held its own or has actually fallen off.

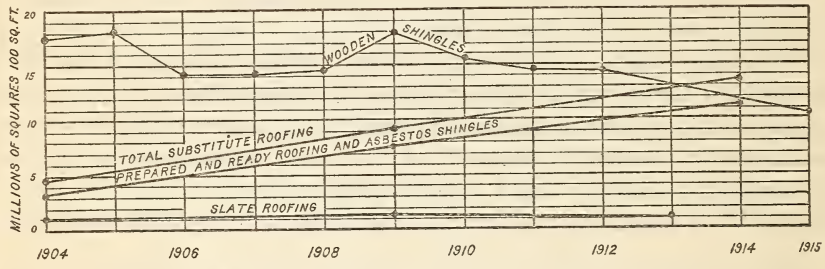

FIG. 14.—Reported production of roofing materials in the United States.

The data on wooden shingle production shown in figure 14 are taken from various census reports and Forest Service publications. They indicate that from 1904 to 1912 the reported output in the United States fell from 17½ to 14½ millions of 100-foot squares and between 1909 and 1915 from 18 to 12¼ millions. These data are open to the same questions on the score of varying completeness of reports as those given for lumber production. It seems probable, however, that the production of wooden shingles has not increased and that it may have fallen off as much as 37 per cent between 1909 and 1915. The 1915 census conducted by the Forest Service shows a reported production of about 11,282,000 squares and an estimated total production of about 12,000,000 squares. Importations of shingles are reported by the Bureau of Foreign and Domestic Commerce as 637,846,000 shingles in 1901, 824,721,000 in 1905, 674,041,000 in 1910, 1,248,726,000 in 1914, and 1,775,130,000 in 1915. The last number is equivalent to about 2,100,000 squares, so that apparently the total consumption in the United States in 1915 was slightly lower

than the reported production in 1912. That in turn was unquestionably less than the actual consumption. The determination of the extent of substitution in roofing is somewhat further involved by the use of the wooden shingle to a considerable but unknown extent for house siding.

On the other hand, the production of all substitute roofings according to the best data available increased from about 4½ million squares in 1904 to about 13½ in 1914, or 200 per cent. Table 7 shows the percentages of the various substitute roofings entering into the total of 13,605,835 squares manufactured in 1914.

TABLE 7.—*Percentage of the total production of substitute roofings supplied by each.*

Cement tile, and miscellaneous	0.4
Clay tile	1.1
Asphalt shingles	2.4
Metal shingles and tiles	6.3
Slate (1913)	8.2
Prepared and ready roofings, including asbestos roofings and shingles	81.6

Data on slate tile were secured from the 1913 report of the Geological Survey on "Mineral Resources of the United States." Reports on asphalt, asbestos, and metal shingles, cement and clay tile, and prepared and ready roofings were obtained by the Forest Service through correspondence with manufacturers, but do not constitute a complete census.

The following discussion of individual types of substitute roofings, taken up in the order indicated in Table 7, brings out the comparative increases in their rate of production. Reports were secured from only two makers of cement tile, and their production of less than one-half of 1 per cent of the substitute roofings in 1914 is too small to influence the total. The output of clay roofing tile, representing about 1.1 per cent of all substitutes in 1914, increased, as shown in figure 15 for the 12 firms reporting, from 20,343 squares in 1904 to 154,145 in 1914. Reports from 11 manufacturers, none of whom made asphalt shingles in 1904 and who manufactured but an insignificant quantity in 1909, show in 1914 (figure 15) a production of 311,111 squares, or 2.4 per cent of the total substitute roofing. The reports from 16 makers of metal tile and shingles (figure 16) show an increase of approximately 1,400 per cent in production, from 56,618 squares in 1908 to 853,024 in 1914, practically all of which is due to the increased use of metal tile. The total represents about 6.3 per cent of the substitute roofing now manufactured.

Slate is second in consumption among the substitute roofings, probably representing about 8.2 per cent of the total in 1914. The production of slate roofing fell from 1,233,757 squares (figure 14) in 1904 to 1,133,713 in 1909 and 1,113,944 in 1913. The output in

1914 is assumed to be essentially the same as in 1913. This substitute for wood thus is hardly holding its own. The production of prepared and ready roofings, including asbestos roofings and shingles, shown in figure 14, increased 240 per cent from 1904 to 1914, or from 3,267,678 squares to 11,106,966. This class includes about 81.6 per cent of the total production of substitutes in 1914.

The decrease in sales of wooden shingles due to the inroads of substitutes was estimated by retail dealers (Table 1) at 16.2 per cent from 1907 to 1909 and at 35 per cent from 1907 to 1914 (Table 3). The entire production of substitute roofings shown in figure 14 probably represents a corresponding decrease in the use of wooden shingles. This amounts in 1914 to 13,605,835 squares; whereas the production of wooden shingles, if assumed to be the same in 1914 as in 1912, amounts to 14,430,000 squares. Shingles thus appear to have held 51.5 per cent of the trade, and substitutes, 48.5 per cent. Several types of

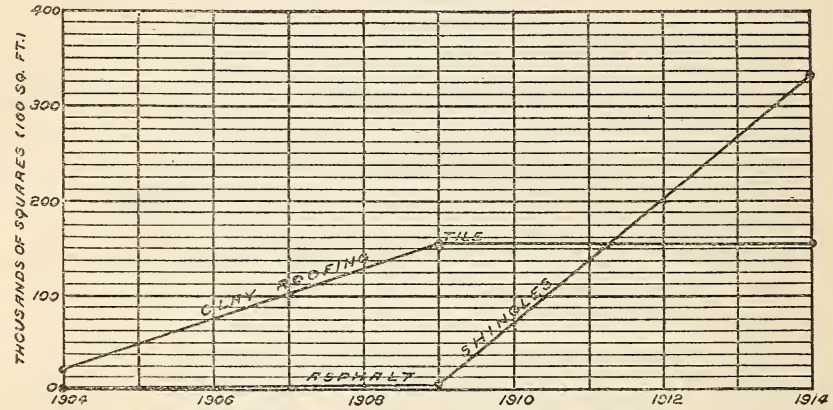

FIG. 15.—Production of asphalt shingles and clay roofing tile in the United States.

roofing which are not necessarily competitors of the wooden shingle are not included in the foregoing estimates, including tar and gravel roofing, corrugated-iron roofings, and tin roofings except tin shingles. The present substitution for the wooden shingle amounts, therefore, to about 50 per cent of the current consumption of all roofing material. Substitution has been increasing rapidly and promises to continue. The strongest competition during the last ten years has come from composition roofings and asphalt shingles.

Upon the assumption that each inch of wood in thickness will cut three and one-half shingles and that there are 833 shingles per square (100 square feet), a square of shingles is equivalent to 106 feet board measure. The total substitution for the wooden shingle now amounts, therefore, to approximately 1,440,000,000 board feet. This, however, is not a replacement of sawed lumber.

LATH.

The wooden lath is being replaced by two distinct classes of products, wall and plaster board and metal lath. The economic and industrial forces which are leading to this substitution are those already discussed, the building code, new forms of construction demanded by present-day tastes, advertising, comparative costs and utility, and the like. The discussion is separated from general building and construction, of which it is logically a part, because the replacement is very largely for wood in other forms than lumber.

Wall and plaster board replace plaster as well as lath, and, to a degree also, finishing lumber in certain classes of construction. Wall board is also used to a certain extent where lath and plaster never would have been employed. It is quite impossible to make a short

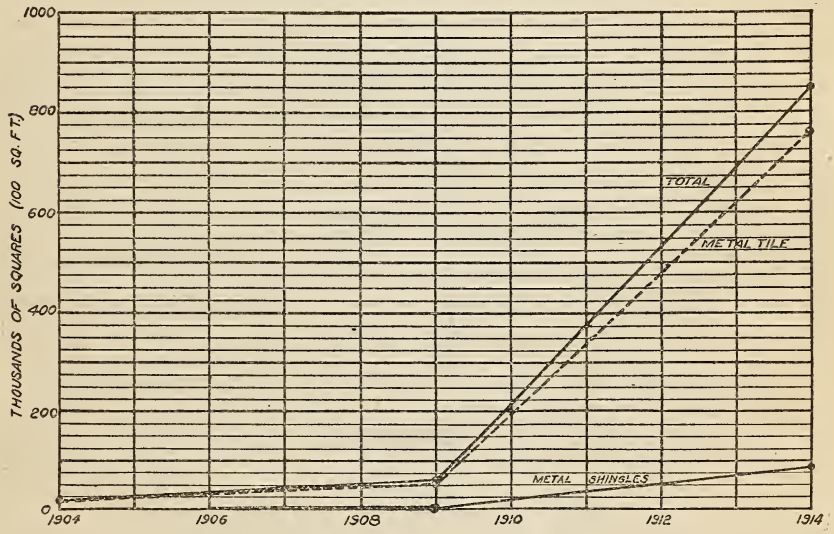

FIG. 16.—Production of metal shingles and metal tile in the United States.

definition of wall or plaster board which will be applicable to all of the varied products of this character now manufactured; but as the basis for a census the Forest Products Laboratory used the following:

By wall board is meant those stiff composition building boards made up of three or more plies of wood pulp or paper board. They are usually intended to form interior walls with panel effects.

By plaster boards is meant those composition boards consisting principally of mineral plaster with or without liners of paper board. They are usually intended to be plastered over for interior finish on walls and ceilings, although at times they may be used without additional plaster in the same manner as the wall boards above mentioned.

Asbestos wall boards are included under plaster boards.

Table 8 is a compilation of the replies received from all the known wall and plaster board manufacturers in the United States. It is believed to be practically complete.

TABLE 8.—*Wall and plaster board production in the United States.*

Kind of board.	Output.		
	1904	1909	1914
	Square feet.	*Square feet.*	*Square feet.*
Wall board	.....	22,402,810	194,974,408
Plaster board	.....	47,518,550	112,176,786
Plaster board asbestos	.....	1,209,278	1,063,424
Total building board replacing lath and plaster	4,502,713	71,130,638	308,214,618

The growth in this industry during 10 years is from a negligible production to 308,214,618 square feet, a percentage increase of 6,745; while during the 5 years from 1909 to 1914 the increase was more than 300 per cent. Further, the total area of board manufactured in 1914 was nearly 19 per cent of the total area of wooden lath pro-

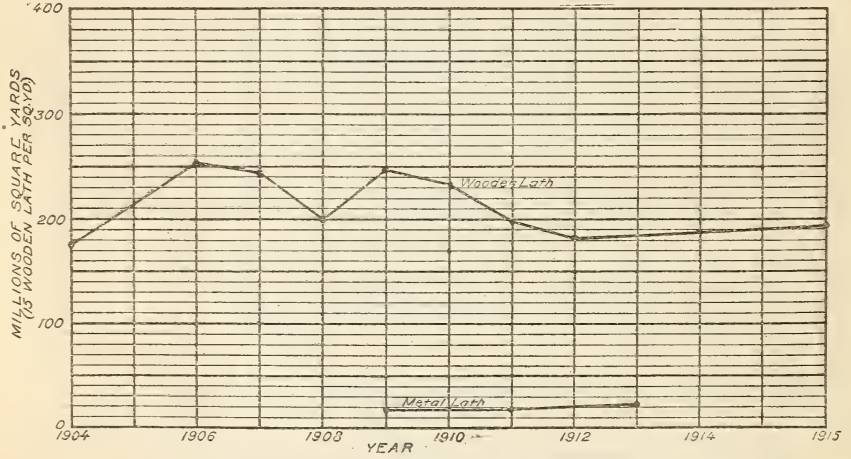

FIG. 17.—Production of wooden and metal lath in the United States.

duced, on the basis of 15 lath per square yard. The output of the wall and plaster board industry has, in other words, risen in 10 years to almost one-fifth of the output of the wooden-lath industry, with every indication of continued future growth. The decrease in wooden-lath production discussed below has undoubtedly been due largely to wall and plaster board competition.

The production of metal and wooden lath is shown in figure 17. The data on wooden-lath production are taken from Forest Service and census publications and converted to an area unit on the basis of 15 lath to 1 square yard of surface. While the census reports for different years undoubtedly vary in completeness there unquestionably was a falling off in lath production between 1906 and 1915. The amount of the falling off may be nearly 30 per cent.

A census of metal-lath production taken by the Forest Products Laboratory included manufacturers of expanded metal, sheet, and

wire lath, and represents the outputs of 20 mills. The increase in metal-lath production did not have a marked effect upon the wooden-lath industry during the three years for which data are available, although the production was approximately two-thirds of the output of wall and plaster board according to the latest figures available on each.

Wall and plaster board have been the greatest factors in replacing wooden lath. Practically the entire displacement has occurred during the last 10 years. Metal lath to a certain extent are used for purposes for which wooden lath are not suitable. Present indications are that the production of competitors of wood in this field will continue to increase rapidly and that wooden lath will have difficulty in holding its own.

Assuming that 1 square yard of lath is equivalent to 3.75 feet board measure and that 15 lath are required per square yard, the present substitution of 22,615,915 square yards of metal lath and 34,246,089 square yards of wall and plaster board approximates 210,000,000 board feet annually. Lath are a by-product of the lumber industry, and the substitution indicated does not affect lumber production or consumption directly. Wall board, which is responsible for approximately 35 per cent of the substitution, is itself a wood product, so that the net replacement of wood is considerably less than 210,000,000 board feet. Indeed, the amount of wood used may even be increased through these changing forms of construction. The figure given in Table 24 is subject to this qualification.

OTHER USES OF WOOD IN WHICH THERE IS SUBSTITUTION.

The second group of wood uses in which there is substitution, that is, those other than building and construction, is so miscellaneous in character that it does not lend itself to a single descriptive term. Some of these uses are closely related to those included under building and construction, and they are separated, more or less arbitrarily, largely because specific data are available on the lumber they consume. Substitution in any particular use displaces lumber or wood in other forms, or both. In addition to a considerable amount of other wooden products, the second group of uses as a whole requires something less than 11 billion feet board measure of lumber yearly, or roughly the difference between the 27 billion feet of lumber used in building and construction and the total consumption for all purposes of 38 billion feet (in 1915)

BOXES.

In spite of higher initial costs, substitutes have replaced wood in many cases because consumers have believed that in the long run the cost would be equalized or more than offset by greater service, smaller risk, or lower maintenance charges. The primary factor, however, which has brought about the substitution of the

fiber container and the veneer package or box for the wooden or shook box, has been lower initial costs and lighter weights, which result in lower freight charges. While competition has centered on cost and weight, other factors, such as comparative reliability under all conditions, will undoubtedly continue to be the subject of controversy between manufacturers of containers, purchasers and their associations, freight classification and transportation agencies, and public railroad and commerce commissions, to the varying advantage and disadvantage of the different types of containers. Controversy is made possible largely by lack of authentic information, a lack which gradually is being supplied by scientific tests and the preparation of standard specifications and by the systematic collection of statistics on breakage, losses, etc. The comparative resourcefulness and aggres-

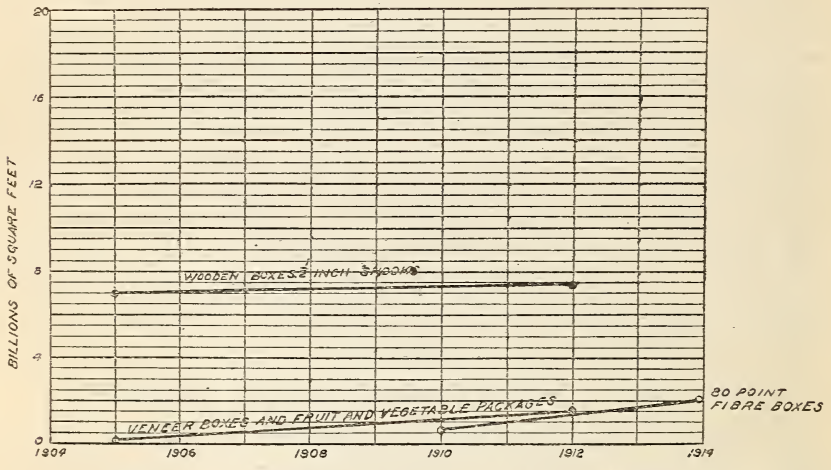

FIG. 18.—Production of shook, veneer, and fiber boxes in the United States.

siveness of the industries concerned in advertising and marketing their products has also affected the situation.

The use of square containers has increased rapidly during the last decade, and particularly during the last 5 years. General knowledge of the situation indicates that the increased use is greater than that required by normal business development because of the trend in merchandizing to the wide use of small packages, mostly pasteboard, which require square fiber or shook containers for shipping.

The comparative production of the shook box, the veneer box and package, and the fiber container is shown in figure 18 as nearly as the data available permit. In part, these consist of estimates based upon incomplete returns secured in statistical and other studies of the industries. The only complete data available on the consumption of wood for packages are total figures which include the material from which all three types are manufactured. A lumber consump-

tion in 1912 of 4,550,000,000 board feet for shook and veneer boxes and fruit and vegetable packages is the most reliable figure available. It was compiled from wood-using industry studies conducted by the Forest Service from 1910 to 1913 in cooperation with various State offices and institutions. Of the total of 4,550,000,000 [1] board feet reported, it is estimated that 700,000,000 log scale feet were used for veneer boxes and fruit and vegetable packages, leaving 3,850,000,000 board feet, lumber measure, or its equivalent of 7,700,000,000 square feet, for box shooks. This equivalent was calculated, for purposes of comparison, by assuming that the average box shook is about one-half inch thick, and hence that a foot board measure is equal to two surface feet of shook. Further, of the 700,000,000 board feet, log scale, used for veneer containers, it is estimated that 250,000,000 feet were used for veneer boxes and an additional 50,000,000 feet for fruit and vegetable packages, which compete directly with the shook box. This total of 300,000,000 board feet, including 3 and 5 ply as well as single-ply veneer containers, is equivalent to about 1,500,000,000 square feet of box shook, on the assumption that veneer materials average about one-eighth inch in thickness.

Forest Service Circular 78, "Wood Used for Packing Boxes in New England," shows a consumption by box manufacturers of 600,493,000 board feet in 1905. The later State wood-using industry studies show that New England consumes 16.53 per cent of all box material. Upon this basis the total consumption of box material in the United States in 1905, including veneer stock as of 1912, was 3,632,747,000 board feet. Great accuracy can not be claimed for this figure. It is believed, however, to be more reliable than the estimates made by the Forest Service in Circular 177. Nor is there an accurate basis for dividing this total between the various types of boxes manufactured. The likelihood is, however, that the consumption for veneer boxes and for veneer packages which competed with shook boxes did not exeed 20,000,000 board feet, log scale, which is equivalent to 100,000,000 square feet. It is estimated that an additional 70,000,000 board feet, log scale, went into veneer packages not competing with the shook box, leaving a balance of 3,542,757,000 board feet, or 7,085,494,000 square feet for shook boxes themselves.

If these estimates are correct, shook-box production increased from approximately 7,085,494,000 square feet in 1905 to 7,700,000,000 square feet in 1912, while veneer boxes and packages increased from 100,000,000 square feet to 1,500,000,000. While accuracy is not claimed for these estimates, they probably indicate the general trend in production. Data since 1912 are not available.

[1] Because of the form in which the reports were secured, this total includes feet board measure under two forms of measurement—lumber measure for shook material and log scale for the veneer stock.

A census made by the Forest Service in July, 1910, showed an annual consumption of approximately 116,000 tons of fiber board in the manufacture of containers. This is equivalent to approximately 748,000,000 square feet of 80-point board. Statements secured in October, 1914, from 21 manufacturers of shipping containers indicate an average increase in output over 1910 of 186 per cent. On this basis, without additions for possible new plants, the total 1914 production was approximately 331,760 tons, equivalent to 2,140,280,000 square feet of 80-point board.

Forest Service Circular 177 reports the proportion of materials in fiber boxes as 57 per cent chip, 22 per cent straw, 16 per cent wood pulp, and 5 per cent jute. Chip is made up of newspapers and other waste fiber products. While, therefore, the fiber is a substitute for the shook box, it is composed partly of wood products and is much less a substitute for wood than for lumber. The production of fiber containers is increasing, and during the last decade particularly they have become an important competitor of the shook box. While the production of shook boxes, as already indicated, probably increased up to 1912, the percentage of increase in the veneer boxes and packages was much greater. So far as can now be foreseen, there is a logical field for each of the types discussed, which will be more clearly defined when sufficient authentic data become available to permit the adoption of scientific specifications and shipping regulations. It is not unlikely that there may be at least a gradual increase in the consumption of all classes of boxes. Comparative use will be influenced by any wide variations in the price of raw materials.

The fiber box in 1914 replaced approximately 1,070,000,000 feet of wood, board measure, assuming that all fiber board averaged 80-point and that each square foot of fiber board replaced one-half foot of lumber. On the other hand, the veneer box and package in 1912 replaced material to an estimated amount of 300,000,000 board feet, log scale. This is equivalent to a replacement of 1,500,000,000 square feet of box shooks, or 750,000,000 board feet of lumber suitable for shooks. Since the total replacement of lumber apparently amounts to about 1,820,000,000 board feet, an estimate of 1,500,000,000 feet replacement through the use of other types of boxes would seem to be conservative.

The above figures are based in part upon estimates, and should therefore be accepted with caution, more as an indication of tendencies than an exact statement of facts. The exact amount of substitution for wood as distinct from lumber can not easily be determined. Approximately 70 per cent of the material going into fiber boxes is wood, and the veneer box and package are made entirely of wood. It requires less wood to make either than to make a shook box of the same size. Table 24 must not therefore be understood

as assuming that the substitution is the same for wood as for lumber. A large part of the replacement of shook boxes is by substitutes consisting largely or altogether of wood in other forms.

RAILROAD CARS.

Railroad-car shops have been important consumers of lumber, and in certain sections the sawmills have depended upon them to take much of their product. Annual purchases for car materials have exceeded 1,250,000,000 board feet. Furthermore, orders for cars have been followed closely during the last decade or more as a barometer of the general financial condition of the country. During the last 10 years, however, both passenger and freight cars constructed partially or wholly of steel have practically replaced the all-wood car in North America. Among the powerful influences necessary to bring about such a radical change has been the "safety-first" propaganda in all its bearings. This has affected the passenger car chiefly. This movement has assisted materially in reducing the consumption of wood until the all-steel passenger train is now offered to the traveling public as affording opportunity for travel with the least risk to life or limb. The passenger-car agitation has undoubtedly been instrumental in bringing about changed forms of construction in freight cars as well.

Rapidly increasing traffic demands rising costs of construction, and in certain cases stationary or even falling freight rates have stimulated the development of locomotives with a greatly increased hauling capacity. Stronger cars have been necessary in the longer trains which these locomotives handle. Car capacity has grown with locomotive development. In addition, there are said to be some 95 or 100 hump yards in the United States in which cars, in gravity switching, receive more severe punishment than ever before. Freight-car designers have been influenced by the desirability of developing forms of construction which will reduce the annual claims upon American railroads for damaged freight, now said to aggregate $40,000,000. This general development has been primarily responsible for the steel underframe and the all-steel construction. The objections to the all-wood car, known through long years of experience, have led to new forms of construction which may in turn have to be fully tested in use before their comparative merits are finally determined. To a certain extent, the change has undoubtedly been due to a much more exact knowledge of the properties of steel as a construction material than of wood. The more concentrated organization of the steel industry has also led to better information regarding the use of its products and to more aggressive and skillful merchandising. It is not certain, however, that stable types have yet been developed in either the freight or passenger car, so far as the material of construction and the manner of its use are concerned, although the American

Railway Association has done a good deal of work toward the development of standard types.

Both freight and passenger cars are, for the purpose of this discussion, classified as all-wood, steel underframe, and all-steel cars. The second class includes all cars with a composite underframe, steel underframe, steel frame and underframe, and all others which do not logically fall into either the first or the third class. The data upon

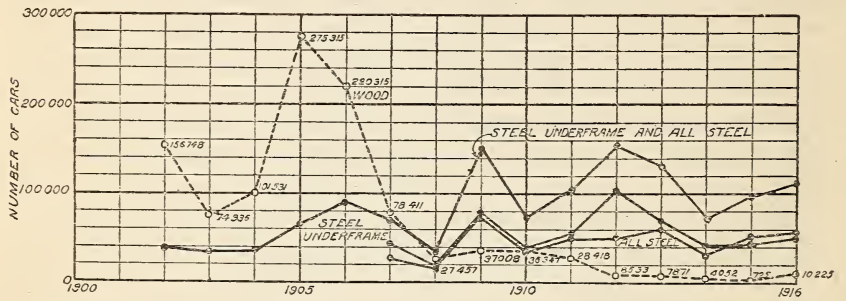

FIG. 19.—Freight cars ordered by railroads in the United States, Canada, and Mexico.

which the discussion is based are taken largely from the annual compilation by the Railway Age Gazette of freight and passenger car orders for use in the United States, Canada, and Mexico.

Car orders, as shown by figure 19 for freight and by figure 20 for passenger cars, are exceedingly sensitive to general financial conditions; probably more so than any of the other products discussed. Freight-car orders varied from more than 335,000 in 1905 to 65,000 in 1908, 190,000 in 1909, and 80,000 in 1914. The curves for indi-

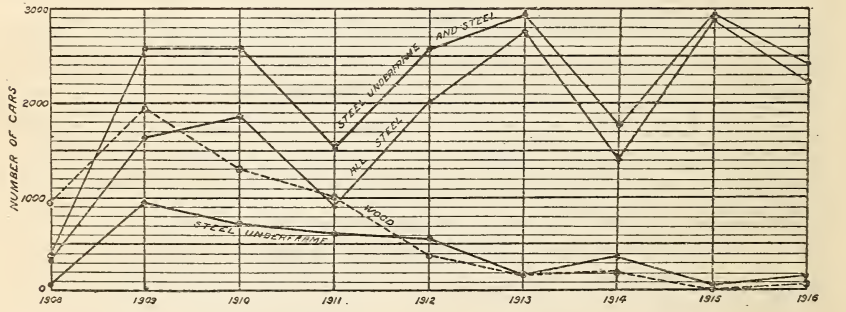

FIG. 20.—Passenger cars ordered by railroads in the United States, Canada, and Mexico.

vidual classes of cars are further complicated by substitutions of one for another; and that for all-wood cars has been subject to the greatest change. All-wood freight-car orders fell from 275,315 in 1905 to 27,457 in 1908, or practically 90 per cent, and to 725 cars in 1915, or more than 99 per cent—a truly remarkable change within 10 years. Furthermore, all-wood car orders, which in 1905 made up 80 per cent of the orders for all freight cars, formed only 5 per cent in 1914.

While the 1914 orders for all steel and steel underframe cars were but slightly greater than in 1905, the general tendency of this curve is plainly upward.

The curve for the all-wood freight car shows strikingly the trend in construction, but only by inference the amount of present substitution of steel for lumber. Data bearing on this point have been obtained by securing estimates from car constructors, supplemented by studies in the Forest Service, of the average amount of wood used per car in each of the various types, such as box, flat, gondola, refrigerator, etc. The total lumber consumption for the year was then determined and divided by the total number of cars constructed. Figure 21 is based on these data and shows the average amount of wood used per freight car from 1900 to 1916. It is believed to be sufficiently accurate to illustrate closely the trend in lumber use in freight-car construction. The average amount of lumber used per car has, on the whole, fallen off steadily between 1913 and 1916. The average amount of wood used per car fell from 5,140 board feet

FIG. 21—Wood used in freight-car construction in the United States.

in 1900 to 2,309 feet in 1916, 55 per cent, despite the fact that the average car capacity has been gradually increasing during this period.

While the number of passenger cars ordered is small, as compared with freight cars, the same general tendencies in construction are illustrated (fig. 20). Since 1909 the number of wooden cars ordered has fallen off regularly, so that in 1913 and 1914 it was only 6 and 10 per cent, respectively, of the total number ordered, whereas in 1909 it was 42 per cent. In 1915 one wooden car was ordered. Manufacturers estimate the average amount of lumber used per car as follows:

TABLE 9.—*Manufacturers' estimate of the average amount of lumber used per passenger car.*

Year.	Number of cars on which estimate is based.	Average amount per car.
		Feet b. m.
1900	564	21,914
1903	990	21,888
1906	1,503	18,444
1909	1,412	10,363

During this period the average amount of lumber used per car decreased 11,551 board feet, or more than 50 per cent. A comparison of the curves of steel and wooden passenger cars ordered indicates a further reduction between 1909 and 1914 (fig. 20).

The average amount of wood in an all-wood freight car is estimated at 5,500 board feet and that in the average car ordered in 1914 at 2,160 board feet. Substitution on this basis amounted to 3,340 feet per car, or slightly in excess of 260,000,000 board feet for the 78,240 freight cars ordered in 1914. In the case of passenger cars the total is negligible, because of the small number ordered. In considering the total substitution figures just quoted it should be remembered that 1914 was an off year and that orders during a normal year would probably be 100 per cent greater, with a corresponding increase in the total substitution of steel for lumber. For this reason no reduction is made in the figures quoted for cars ordered in Canada and Mexico. It seems hardly possible that the use of wood in building cars can fall off much further; but increases in its use can be brought about only by proving the superiority of all-wood or partly wooden cars over all steel construction, or through the necessity for placing orders for the cheapest type of cars, or through the inability of the railroads to secure prompt delivery of steel cars.

FURNITURE.

While both reeds and metals are being substituted in considerable quantities for lumber in furniture making, it has been possible to secure data only on the latter. One of the principal lines of development has been in metal office furniture, for which reduced fire risk is claimed. The increased use of metal beds during the last 20 years is also a striking example of replacement, carried to such a degree that at present few but the higher-priced beds are made of wood. Metal furniture in general has been substituted in spite of its higher cost, while reed furniture has been aided in competition by its lower cost and lighter weight.

Census figures for 1910 show the total value of metal furniture manufactured in 1909 by 152 firms to be $24,396,377. This undoubtedly includes metal beds, retail shop tables and chairs, lockers, and a wide variety of furniture for home and business purposes. No data for preceding years are available. To determine the general tendency in the metal-furniture industry, the Forest Service secured reports from 32 manufacturers for the years 1904, 1909, and 1914. The value of the metal furniture, filing cases, lockers, shelves, map tubes, and similar equipment manufactured was requested. The results shown in figure 11, while obviously covering only a fraction of the output, are believed to indicate the general trend in the entire industry. The output of the firms reporting increased from approximately $200,000

in 1904 to $7,000,000 in 1914, or 1,450 per cent. The increase between 1905 and 1914 was 200 per cent.

The total production of metal furniture in 1914 may, therefore, for the purpose of determining the amount of substitution, be conservatively placed at the figure reported by the census in 1909, $24,396,377. The substitution may then be estimated, as in the case of metal trim, by assuming that each ton of metal furniture has a value of $125 and replaces 1,000 feet of lumber, board measure. On this basis the substitution exceeds 175,000,000 board feet annually. The production of metal furniture will increase in the future if past tendencies indicate what to expect, although the use of wood in furniture making, which now amounts to nearly 950,000,000 board feet annually, may be expected to increase also.

VEHICLES.

The one big factor which has lessened the demand for wood in the horse-drawn vehicle industry has been, not a substitute for wood, but a substitute for the horse-drawn vehicle, the automobile. The extent of the development in the automobile industry is indicated in Table 10, taken from the census report for 1910:

TABLE 10.—*Automobile production.*

Year.	Passenger autos.	Business autos.	Total.
1899	.....	.....	3,897
1904	21,281	411	[1] 22,386
1909	123,338	3,255	[1] 127,731

[1] Includes a limited number of unclassified machines manufactured by establishments engaged primarily in the manufacture of other products.

The National Automobile Chamber of Commerce reports a production during the year ending June 30, 1915, of 665,826 passenger and 37,700 business machines, totaling 703,526. This truly marvelous growth of 18,000 per cent, from 3,897 to 703,526 machines, in less than 16 years, has not only absorbed the normal increase in the horse-drawn vehicle industry, but has actually decreased its output.

The production of horse-drawn vehicles from 1889 to 1909 is reported as follows in the censuses of 1900 and 1910:

TABLE 11.—*Production of horse-drawn vehicles.*

Year.	Pleasure vehicles.	Business vehicles, sleighs, and sleds.	Total.
1889	841,305	523,371	1,364,676
1899	904,639	689,652	1,594,291
1904	937,409	773,921	1,711,330
1909	828,411	680,827	1,519,238

The secretary of the Carriage Builders' National Association estimates the carriage output of 1913 at about 70 per cent of the maximum output for any year, and that of 1914 at less than 55 per cent. This estimate indicates that the decrease first shown in 1909 was the beginning of a decline in production which has become more rapid as the output of automobiles has increased. While automobile production has increased 681,140 machines annually, horse-drawn vehicle construction has fallen off 770,099.

In addition to the decreased production caused by the competition of automobiles, there has been an actual substitution in horse-drawn vehicles of other materials, such as steel and aluminum, for wood. This has been due mainly to the possibility of reducing costs and also in part to the increasing difficulty of securing sufficient quantities of high-grade wood. Table 12, compiled from reports made to the Forest Products Laboratory by the leading manufacturers of business and pleasure vehicles, indicates the extent of such substitution between 1904 and 1914.

TABLE 12.—*Lumber used in horse-drawn vehicles.*

Year.	Number of vehicles on which statement is based.	Total lumber used.	Lumber per vehicle.
		Feet b. m.	*Feet b. m.*
1904	175,294	46,812,344	267
1909	225,185	63,732,222	283
1914	202,549	50,834,375	251

These data indicate a decrease of 32 board feet per vehicle from 1909 to 1914, or about 11 per cent. This may be due altogether to substitution or in part to variations in the number of vehicles of different sizes and types of construction. If the former is true, and if this proportion holds true for all the vehicles made in 1914, the substitution on the 941,231 vehicles manufactured totals slightly more than 30,000,000 board feet. This is made up in part of lumber and in part of wood in other forms. While the basis for this estimate is unsatisfactory, the amount is probably conservative, since the substitution undoubtedly began before 1909. Under the assumptions given the total use of lumber for horse-drawn vehicles decreased from 429,944,354 board feet in 1909 to 236,248,981 in 1914, a difference of 195,695,373 board feet.

The automobile, in its early days, used an appreciable amount of wood in body construction; but the present-day passenger machine contains little wood other than wheels, floor boards, steering-wheel rim, and other minor parts. Substitution has taken place mainly to reduce costs and avoid the increasing difficulty of obtaining sufficient

quantities of the high-grade lumber required. A considerable amount of lumber is still used in the construction of the bodies of commercial automobiles. When the marvelous increase in the number of cars built is taken into account, it seems reasonable to suppose that the decrease in the amount of wood per car has been more than compensated by the increased number of cars built and that no actual decrease in the total consumption of wood for automobile construction has taken place.

The total number of automobiles constructed is only slightly less than the decrease in the number of horse-drawn vehicles. In order to keep up the use of lumber in the vehicle industry as changed by automobile competition it would, therefore, be necessary to use about 250 board feet per car. The actual quantity used is not known, but is believed to be considerably less than this quantity. The estimate of 30,000,000 board feet annually is believed, therefore, to be a very conservative figure for the displacement of lumber in the vehicle industry as a whole.

The output of horse-drawn vehicles will probably continue to fall off with increased competition from the automobile, and with it the proportionate use of wood in the vehicle industry. In addition, a gradually decreasing use of wood per horse-drawn vehicle may be anticipated as the result of increasing substitution of steel and other metals.

SHIPS.

Since the days of the clipper ship, when sailing vessels built of wood in the United States carried the American flag upon all the seas, shipping has undergone a radical change. The United States became one of the world's greatest maritime powers in the days of the wooden ship partly because of an abundant and cheap supply of ship timber. The building of iron ships began early in England on account of the shortage of timber. It was taken up much more slowly in the United States until the growing scarcity of timber increased its cost and the great development of the metal industries reduced iron and steel prices to a point which placed the initial cost of the two classes of ships more nearly on a par. According to the census report of 1880, wooden ships of 2,000 tons register in the United States were still costing from $45 to $60 per ton as compared with $85 to $100 per ton for iron ships.

The first iron ship is said to have been built in the United States in 1825. Iron construction increased very slowly thereafter until about 1870, with fluctuations during the latter part of the period, depending upon iron prices. In 1880, however, there were only five or six deep-sea iron sailing vessels under American registry, and the remainder of the tonnage of merchant ships, aggregating 2,366,258 tons, were built of wood.

The development of iron and steel construction, together with that of the steam engine, has made possible a length of hull for which wood is not suitable except as interior construction and finish. Wooden sailing vessels and steamers have been built up to lengths of about 350 feet, but in greater lengths it has been impossible to secure the rigidity of hull necessary for deep-sea navigation.

Besides stimulating replacement through the construction of large ships for which wood is not suitable, the steam engine has been a factor of importance in the case of smaller vessels. The period of development of the steam engine has corresponded closely with the growing use of iron and steel in ship construction. Practically no wood is now used in the construction of vessels of war, except for deck planking and small boats. For such uses as interior trim, furniture, storeroom fittings, armor backing, etc., wood has been abandoned in

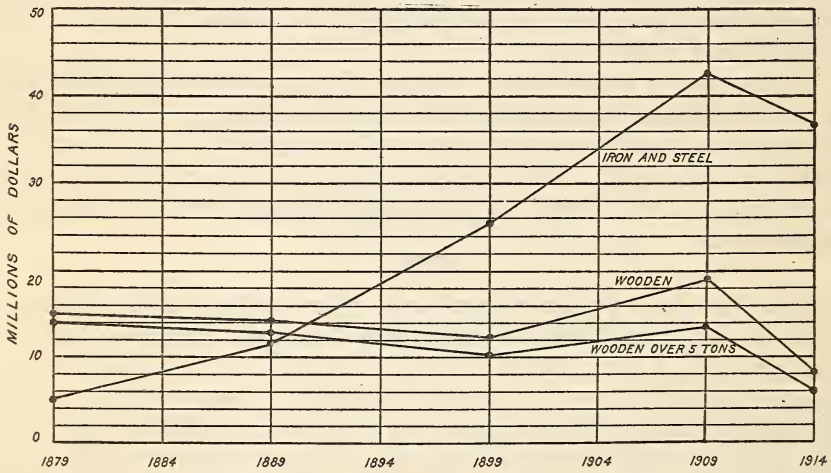

FIG. 22.—Value of ships built in the United States.

favor of steel or other noninflammable material. The same tendency toward substitution in order to decrease the fire risk is believed to exist also in the merchant marine. Other changes in materials and construction, of varying importance, have been made to meet the widely divergent and changing requirements of lake, river, canal, coastwise, and deep-sea navigation.

But few data bearing directly on the displacement of wood in shipbuilding are available. At best they can be used only as a rough indication of the amount of the present substitution of steel for lumber. It is surprising to find that the value of the wooden vessels built in 1909 was greater than during any other census year, including and subsequent to 1879 (fig. 22). On the other hand, the tonnage of wooden vessels, a better index of the amount of lumber used in construction, decreased steadily until 1914 (fig. 23).

The falling off between 1879 and 1914 amounted to a gross tonnage of approximately 250,000, or more than 50 per cent. The total annual tonnage of ships of all kinds constructed between 1879 and 1914 has shown comparatively little variation, and tonnage losses in wooden vessels have been largely absorbed by steel.

The value and tonnage of steel and iron vessels constructed from 1879 to 1914 are also shown in figures 22 and 23. The values of steel ships increased very rapidly to 1909, since when it has fallen off. Tonnage, on the other hand, began to fall off in 1904, and probably continued to decline until the exceptional demand for bottoms in 1915 and 1916 resulted in an increase. Very surprising is the fact that steel values did not exceed wood values in ship construction until after 1899; and that steel tonnage did not overtake wooden tonnage until between 1904 and 1909.

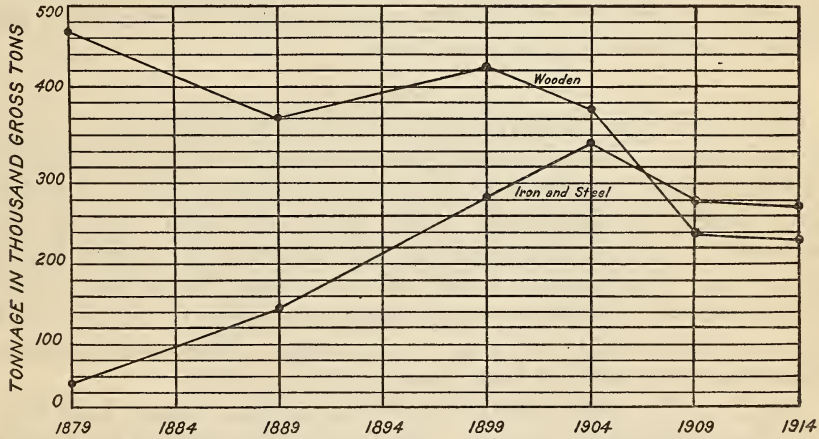

FIG. 23.—Tonnage of ships built in the United States exclusive of Government shipyards.

The Bureau of the Census has not obtained statistics on the amounts of wood used in steel and wooden vessels since 1899, owing, it is understood, to the difficulty of obtaining satisfactory data. The lumber consumed in shipbuilding in that year, including repairs, according to the census data, was 525,271,000 board feet, and the total tonnage constructed was 680,000. This is equivalent to 772 board feet per gross ton. In 1914 the total tonnage constructed possibly reached 450,000. This would, on the 1899 basis, indicate a wood consumption of 347,400,000 board feet. The actual consumption shown by the wood-using industry studies conducted by the Forest Service was approximately 200,000,000 board feet, indicating a substitution of about 150,000,000 feet. This figure makes no allowance for the considerable substitution which occurred prior to 1899. On the other hand, it does not take into account the use of steel in hulls too long for wooden construction, which is

not regarded as substitution. Since the former figure is probably larger than the latter, it is believed that 150,000,000 feet is a conservative estimate of the replacement.

The decreasing demand for wood in shipbuilding which has accompanied the falling off in the construction of wooden ships, is an indication of future tendencies. There is probably also an increasing substitution of steel for wood in interior ship construction. The continued use of wood, however, for certain types of ships, such as small coastwise freighters, for certain kinds of interior work on steel ships and for small boats, seems assured. Variations from general tendencies for comparatively short periods, because of high prices for raw materials or inability to secure delivery, are to be expected. At present, high steel prices are accompanied by an exceptional demand for bottoms. This has led to a resumption of wooden-ship building on a considerable scale. Improved preservative processes for wood against fire and decay may also tend to counteract the general trend toward steel construction.

SILOS.

Green corn was first preserved for winter feeding in the United States in 1875. One silo was reported to have been built in 1876 and another in 1879, according to United States Department of Agriculture Farmers' Bulletin 589. Since about 1880 silo building has increased rapidly, and the monthly crop report of the United States Department of Agriculture of July 15, 1915, states that approximately 3.5 per cent of the 1910 corn crop, 5 per cent of the 1911 crop, and 8 per cent of the 1914 crop was cut for silage. This would indicate about 8,364,000 acres of corn stored in silos in 1914.

The first silos were merely excavations in the ground; later they were lined with stone or wood. Many of the first silos in the United States are said to have been constructed of stone within barns. Although lumber was not the first material used, it early became important because of its cheapness, and at one time it is probable that a large proportion of the silos in the United States were built of wood. This proportion is estimated in 1913 at 80 to 90 per cent.[1]

The number of types of silos has increased rapidly. In addition to several types of wooden silos, some of which are plastered or sheathed with metal, are those of monolithic concrete, concrete staves, concrete blocks, tile blocks, brick, steel, plastered metal lath, masonry, and the pit silo with its various modifications.

Data furnished by the Southern Pine Association indicate a total of about 170,000 silos on January 1, 1915, in the 13 States listed in Table 13. This number corresponds closely with an estimate published in 1914 by the "Orange Judd Farmer," with additions for construction up to January 1, 1915.

[1] By M. L. King in "Silos, Construction and Service."

TABLE 13.—*Silos in 13 States of the United States.*

State.	Built in 1913.	Built in 1914.	Number of farms.	Total number of silos.
Wisconsin	8,200	11,200	177,127	53,000
Illinois	5,000	7,000	251,872	24,500
Iowa	3,100	4,000	217,044	20,150
Ohio	3,400	4,300	272,045	15,000
Indiana	2,800	3,200	215,485	14,500
Michigan	1,000	1,250	206,960	12,000
Missouri	2,700	3,100	277,244	9,800
Kansas	1,700	2,000	177,841	8,500
Nebraska	900	1,200	129,678	4,500
Minnesota	500	750	156,137	3,100
South Dakota	400	700	77,644	2,000
Oklahoma	450	550	190,192	2,000
North Dakota	200	350	74,360	1,250
Total	30,350	39,600	2,423,629	170,300

The data on the number of silos constructed per year, 30,350 for 1913 and 39,600 for 1914, are substantiated by an estimate made by the Illinois Silo Co. that the present annual sale of silos is from 36,000 to 40,000.

Data on the proportion of wooden to other forms of silos are meager. The Southern Pine Association estimates that 75 per cent of the 170,300 silos given in Table 13 are built of wood. The "Wisconsin Agriculturist," in a letter dated October 4, 1915, gives Table 14, compiled from replies to inquiries sent to various sections of Wisconsin on the material most commonly used in silo construction:

TABLE 14.—*Materials commonly used in silo construction in Wisconsin.*

Material.	Number of men so reporting.		
	Northern division.	Central division.	Southern division.
Wood	37	24	20
Concrete	17	35	26
Brick	.....	2	4
Tile	.....	2	4
Total	54	63	54

Out of 171 reports received, 78 specify concrete as the popular silo material, 81 wood, 6 tile, and 6 brick. Concrete and wood, in other words, are about equally popular in Wisconsin. It is manifestly impossible to arrive at any definite conclusion from the data presented; however, reports from competent observers lead to the belief that the present sale of wooden silos is nearer 50 than 75 per cent of the total sales, and that this percentage is slowly decreasing. Sales of all the more important types of silos are undoubtedly increasing.

The factors behind the successful competition with the wooden silo of various substitutes are much the same as those previously discussed in other connections. This competition has, through adver-

tising which has emphasized the durable character of its material, aggressive merchandising, exact knowledge of its product, assistance to purchasers in detailed directions for its use, uniform specifications and adherence to them in manufacture, met some success in overcoming the advantage of the lower initial cost of the wooden silo. Based on figures collected by the United States Department of Agriculture on homemade silos in all sections of the country, comparative costs are reported in Farmers' Bulletin 589 as $301.08 for concrete silos averaging 117 tons capacity, and $145 for stave silos averaging 89 tons.

Any figure on the displacement of wood in silo construction is at best an estimate. The Illinois Silo Co. estimates that a silo requires from 2,500 to 3,000 board feet of lumber. If, therefore, substitutes are being used for half of the 40,000 silos now constructed annually, as seems probable, the total annual substitution for lumber reaches approximately 50 million board feet. The silo is growing so rapidly in public favor that the use of all materials from which it can be made is increasing, though it is evident from the meager data available that wood is losing the place of first rank which it formerly held and which it still holds in certain sections of the country.

WINDMILLS.

Substitution of the steel for the wooden windmill has been going on for more than 25 years and has been a comparatively slow and gradual process. It began somewhat earlier than for many of the articles considered, and has never been spectacular or of so pronounced a character as to prevent a gradually increasing use of lumber in windmill construction. The explanation may lie in the fact that many companies which manufacture wooden mills make steel mills also; hence there has been no particular incentive for the exceedingly aggressive competition which has characterized much of the substitution for wood. If this explanation is correct, the demand for the steel mill has arisen from the ultimate consumer and merely reflects in another way the general tendency toward the use of steel in preference to substances regarded as more perishable. The decreasing production of windmills, first evident in 1914, may be due to the general financial situation or may reflect a new competitive element, the gasoline motor pump.

To obtain information upon the approximate extent to which steel has replaced wood in the manufacture of windmills, a partial census was made by the Forest Service, the results of which, incorporating reports from 21 manufacturers, are shown in figure 24. This census is shown to be reasonably accurate by an additional curve indicating the total value of all mills manufactured, as reported by the Bureau of the Census. This follows rather closely the reports made to the

Forest Service of the number of mills manufactured. Between 1889 and 1914, the last probably an off year, the number of mills manufactured by the companies reporting increased more than 360 per cent. Steel mills increased about 430 per cent and wooden mills 250 per cent. On the whole the number of wooden mills increased slowly and steadily, and the number of steel mills as regularly but much more rapidly. As a result, the proportion of wooden mills to the total number manufactured fell from about 37 per cent in 1889 to 23 per cent in 1914, with only one short period of increase, and that very slight. During the last 15 years, when substitution in other fields has been so pronounced, the proportion of wooden to the total number of mills manufactured has decreased not more than 5 per cent.

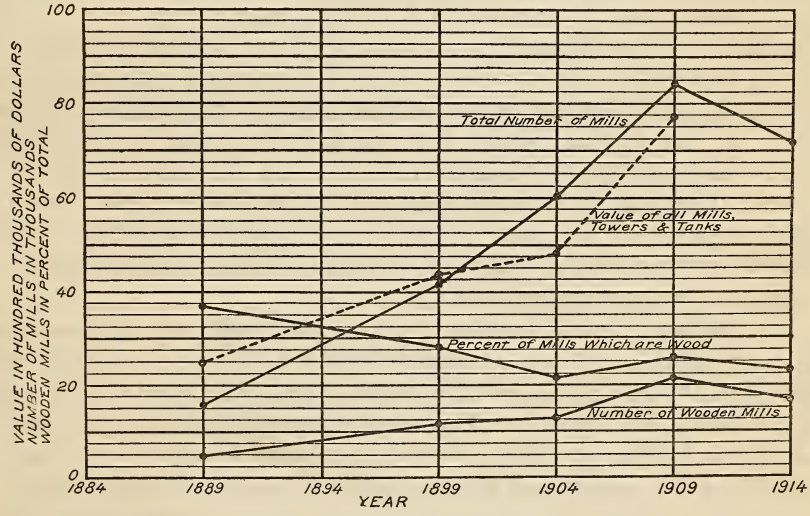

FIG. 24.—Wooden and steel windmills manufactured in the United States.

The total number of mills manufactured in 1914 is estimated at 131,200. This estimate is based upon census figures for 1909, Forest Service data for 1909 and 1914, and an estimated average value per mill tower and tank of $50. Seventy-seven per cent, or approximately 100,000 mills, were of steel. Each steel mill and tower replaced 250 board feet of lumber. On this basis the total substitution in 1914 amounted to approximately 25,000,000 board feet.

The substitution of the steel for the wooden mill has been comparatively gradual during a period of more than 25 years. On the whole, the total number of mills constructed has increased regularly throughout this period, but the greater part of the increase has been absorbed by the steel mill. The number of wooden mills manufactured has increased steadily on the whole, and during the last 15 years the decrease in the proportion of wooden to the total number

of mills constructed has been very small. The only basis on which to hazard a prediction that these general tendencies will not continue is the possibility that the competition of the gasoline pump may restrict the use of all types of windmills.

COOPERAGE.

The markets for both tight and slack cooperage have suffered appreciably from various substitutes, more—however, in the curtailment of normal expansion than in an actual reduction in output. Crude petroleum and its products were first stored and transported in wooden barrels. From one point of view, although not that taken in this publication, the steel storage tank, the steel tank car, the pipe line, the tank steamer, the tin case, the steel barrel, and the tank wagon are all substitutes for the wooden barrel. It is only through the development of this entirely new system of transportation and distribution, however, and the revolution in the economics of refining which it has made possible, that the production of petroleum in the United States has reached its present proportions, more than 300,000,000 barrels in 1915. In the case of the steel barrel, there can be no doubt as to substitution for wood, but the other equipment in part reflects an industrial evolution which, like the skyscraper or immense ocean steamer, involves types of construction for which wood is not suited.

For railroad transportation, the wooden tank car followed the wooden barrel, and was in turn succeeded by the steel tank car, although the last of the wooden tanks were dismantled only a comparatively short time ago. The wooden barrel hauled in wagons was succeeded by the pipe line. The wooden barrel transported in barges and ships was succeeded by the tank barge and the tank ship, respectively. The wooden barrel, at one time a considerable factor in storage, has been largely eliminated, first by the wooden, and then by the steel storage tank. The use of the barrel in delivering oil products has given way largely to the tank wagon and the tin case. Practically all of the crude petroleum produced passes through pipe lines for a greater or less distance. The number of steel tank cars now in use probably exceeds 15,000, with an average capacity of about 8,000 gallons. Oklahoma alone in 1915 is reported to have had 1,552 steel storage tanks of 55,000 barrel capacity, with 17 more building, and 913 tanks with a capacity of from 35,000 to 37,000 barrels. In addition to the petroleum marketed in 1914, it has been estimated that more than 24,000,000 barrels were stored.

These figures are given merely to indicate the requirements of the storage and transportation system in which the wooden barrel was once much more of a factor than it is to-day. In spite of the development of an entirely new and much more efficient system of transportation which delivers oil at a fraction of the former cost, the wooden

barrel has not been entirely eliminated. Large numbers of such barrels are still made and are used in practically all stages in the storage and transportation of petroleum and its products.

The steel barrel was first introduced in the shipment of petroleum products. While admittedly more expensive than wooden barrels, the advantages claimed for steel are greater safety from fire, greater durability, and less possibility of leakage. For a number of uses the wooden barrel has no present substitute, the principal one being probably the aging and shipping of various fermented and distilled liquors. Another is for storing various chemicals and foodstuffs, such as vinegar, which attack metal.

The prohibition movement has undoubtedly limited tight cooperage manufacture, since the industry depends upon the producers of fermented liquors and distilled spirits for the purchase of approximately 30 per cent of its product. Table 15, taken from the Reports of the Commissioner of Internal Revenue, shows an increased production of fermented liquors from 1895 up to 1914, and of distilled spirits up to 1913, but a falling off in both since those years.

TABLE 15.—*Production of fermented liquors and distilled spirits.*

Year.	Fermented liquors.	Distilled spirits.	Year.	Fermented liquors.	Distilled spirits.
	Bbls. of not more than 31 galls.	*Tax galls.*		*Bbls. of not more than 31 galls.*	*Tax galls.*
1895	33,589,784	81,909,771	1912	62,176,694	187,571,808
1900	39,471,593	109,245,187	1913	65,324,876	193,606,258
1905	49,522,029	153,259,378	1914	66,189,473	181,919,542
1910	59,544,775	163,893,960	1915	59,808,210	140,656,103
1911	63,283,123	183,355,527			

The general increase over a long period was undoubtedly reflected until recent years in an increased demand for tight cooperage. It has, to some extent, been offset by the use of tank cars and wooden vats in box cars for railroad shipments. Of greater importance has been the glass bottle, where again the demand for the individual package has undoubtedly resulted in rapidly increasing production and use of bottles at the expense of the tight barrel. The future of tight-cooperage production will in no small degree depend upon the development of prohibition. This is not a substitution, but is cited as one of the influences affecting production.

The production of tight cooperage increased regularly, on the whole, between 1905 and 1911, the only period for which data are available. The output of sets of heading rose from 12 to 30 millions yearly, and the output of staves from 240 to 360 millions (fig. 25). Allowing 21 staves to the barrel, the number of barrels produced in 1911 was about 17,133,000.

Specific data on the inroads upon tight cooperage by the steel barrel are unsatisfactory, since no figures could be obtained upon the

yearly production of the latter. The only data secured were presented at a recent meeting of the Independent Petroleum Marketers of America at Milwaukee, when it was stated that the association owned about 997,440 steel barrels used in marketing its various petroleum products. Others refiners, including the largest in the country, must have at least as many more. Each steel barrel in the long run replaces several wooden barrels, since the former is returned and refilled many times, whereas the latter, though suitable for refilling several times, is frequently sold with its contents and then devoted to other purposes.

With a probable total of 2,000,000 steel barrels in the country, the displacement of at least 1,000,000 wooden barrels annually seems conservative. The extent of replacement of wood by the storage

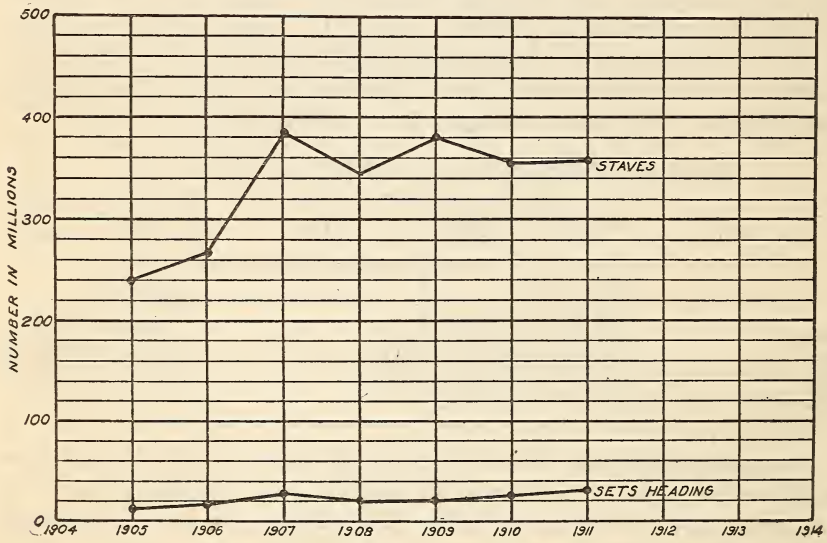

FIG. 25.—Production of tight cooperage in the United States.

tank, pipe line, tank car, tank steamer, tank wagon, and tin case is a matter of judgment as to where substitution begins and ceases. In part it has been allowed for under other classifications. Any specific statement of amounts can at best be only an approximation. A total substitution for tight cooperage, however, including replacement by the steel barrel, of one-third of the last production reported, or 5,700,000 barrels annually, is felt to be conservative.

Slack cooperage has a number of competitors, among which are the metal slack barrel, the veneer barrel, cotton, jute, and paper sacks, the wooden box, and the fiber box and carton. The factors responsible for substitution are variable. Many of the substitutes cost less than the wooden barrel. Cotton and jute sacks, for instance, four to the barrel, cost from 4 to 7 cents each, and paper sacks even less until recently, while the wooden barrel costs from 38 to 46 cents.

There has been a growing tendency to market various food and other products in small containers, such as cloth and paper sacks. This holds true especially for flour, and to a less extent for sugar, cement, plaster, and salt; while another competitor, the carton package, is used for crackers, starch, sugar, table salt, and cranberries.

The small container for food products has gained in popularity because it permits delivery through all intermediaries from the manufacturer to the consumer without reopening and repacking. This is in part offset, however, by the adverse claims of the wooden package that it affords better protection to foodstuffs in transit and marketing, from rodents, insects, and exposure. There are the further conflicting claims of the slack barrel and small container as to economy in storage and in cost and convenience in handling. Manufac-

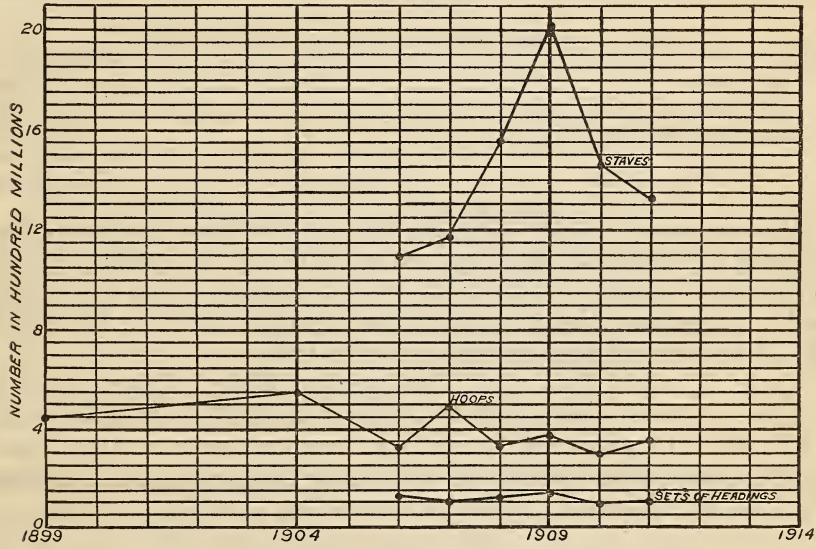

FIG. 26.—Production of slack cooperage in the United States.

turing concerns have eagerly taken advantage of the advertising value of the small package, which can be made in distinctive sizes and shapes and covered with advertising literature. The public can be made familiar with the package through general advertising. Such packages are not adapted to shipment in barrels, and many require square containers. Losses of old markets by the slack barrel have been made up by new markets gained. The unprecedented growth of the Portland cement industry has increased its use. The demand for the barrel was also aided through the declaration of the Apple Growers' Congress in its favor. This, however, affected only the Eastern States, since western packers use boxes for shipping apples.

The production of slack cooperage, shown in figure 26, has probably gained during the period for which data are available, from 1899

to 1911. The number of barrels produced is best indicated by the number of staves. Allowing 16 staves to the barrel, the number of barrels manufactured in 1911 was about 83,000,000. The wide divergence between the curves showing the manufacture of heading and staves is due to the fact that full sets of heading are not used for all barrels. Fluctuations in production follow to some extent the variations in agricultural crops, which directly or in the form of secondary products are shipped in barrels.

The data bearing on the amount of substitution for slack cooperage are more or less fragmentary, but none the less suggestive. Flour is one of the food products which formerly was shipped entirely in barrels, but now utilizes substitute packages very largely. A part of the flour produced in the United States during 1909 is shown in Table 16, which is based upon the report of the Bureau of the Census.

TABLE 16.—*Flour produced in the United States in 1909.*

Kind:	Barrels produced.
Wheat flour	107,108,461
Rye flour	1,591,726
Corn meal and corn flour	27,188,352
Total	135,888,539

If seven-eighths of the 135,888,539 barrels of flour produced was shipped in substitute packages, as estimated in the census report, substitutes replaced 118,902,472 wooden barrels. This is considerably more than the 83,000,000 slack barrels made in 1911, and almost as many as were manufactured in 1909.

Table 17, taken from the "Northwestern Miller," shows that the number of flour barrels sold by Minneapolis shops decreased from 2,617,990 in 1899 to 1,218,770 in 1914, or something over 50 per cent; and further that the percentage of the flour output shipped in barrels fell from 40.3 per cent in 1889 to 6.8 per cent in 1914.

TABLE 17.—*Flour barrels sold by Minneapolis shops and percentage of total Minneapolis flour output shipped in barrels.*

Year.	Barrels.	Per cent.	Year.	Barrels.	Per cent.
1914	1,218,770	6.8	1901	3,450,605	22.0
1913	1,363,365	7.7	1900	3,214,965	21.3
1912	1,291,740	7.6	1899	3,312,590	23.2
1911	1,349,290	8.6	1898	3,250,835	23.0
1910	1,440,670	9.3	1897	3,158,035	26.3
1909	1,555,560	10.4	1896	3,386,460	26.3
1908	1,695,260	12.4	1895	2,718,125	26.0
1907	1,930,145	14.1	1894	3,061,935	32.5
1906	1,969,250	14.2	1893	3,095,505	33.0
1905	2,643,780	18.5	1892	3,404,545	34.0
1904	2,836,520	20.8	1891	2,612,470	33.2
1903	3,129,360	20.0	1890	3,123,945	44.7
1902	3,343,710	21.0	1889	2,617,990	40.3

Cement offers another interesting example. The production in 1912, as given by the United States Geological Survey report on the mineral resources of the United States, was 83,351,191 barrels. This alone would take almost all the slack cooperage produced, if all cement were shipped in barrels. Most of it, however, is shipped in cotton sacks, which are used over and over again. On the other hand, at least one prominent company features in its advertisements the paper cement sacks it uses. The Forest Service has no complete statistics upon the production of these paper sacks, but two concerns alone report an output of more than four and one-half million in 1914. This would account for more than 1,125,000 barrels.

The competition of substitute packages has apparently deprived the slack barrel of markets aggregating at least twice the present production of slack cooperage.

An estimate of the substitution for slack cooperage of one-third of the average production during the last few years is therefore conservative, even with an allowance for the use of paper sacks, etc., which are merely wood in another form. This amounts to approximately 35,000,000 barrels a year.

Allowing 20 feet to the barrel, the substitution for tight cooperage equals approximately 115,000,000 board feet yearly; for slack cooperage, allowing 6 board feet to the barrel, approximately 210,000,000 board feet; the total substitution amounts to 325,000,000 feet annually. The general tendency in both slack and tight cooperage has been toward increased production. This increase bids fair to be comparatively small in the future.

FUEL.

More wood is used for fuel in the United States than for any other purpose. Substitution of coal, oil, gas, and, to a slight extent, electricity has been due largely to the gradually decreasing supply of accessible wood, the high cost of transporting so bulky a material, and the greater convenience of other fuels. The consumption of fuel wood is reported by the Census of 1880 at 145,778,137 cords. As shown by Table 18, by far the most extensive use is for domestic purposes, 140,537,439 cords. It is obvious that the table does not contain any allowance for the vast amount of wood waste and other material consumed as fuel by sawmills.

TABLE 18.—*Wood used as fuel in 1880.*

	Cords.		Cords.
Domestic purposes	140,537,439	Manufacture of brick and tile	1,157,552
Railroads	1,971,813	Manufacture of salt	540,448
Steamboats	787,862	Manufacture of wool	158,208
Mining and amalgamating	358,074		
Mining operations	266,771	Total	145,778,137

Consumption in 1905, as estimated in Forest Service Bulletin 74, had fallen to 100,000,000 cords. In 1910, on the basis of figures quoted in Forest Service Circular 181[1] and the Census Report for 1910, the total consumption had fallen to approximately 90,000,000 cords. Neither of these figures includes the wood used as fuel in sawmills.

These data show a falling off in the use of wood from 145,778,137 cords in 1880 to 90,000,000 cords in 1910. The production of anthracite coal, on the other hand, as shown by the United States Geological Survey statistics, increased from 45,546,970 short tons in 1889 to 60,418,005 tons in 1899; 81,070,359 tons in 1909; and 88,995,061 tons in 1915. The production of bituminous coal during the same period rose from 95,682,543 tons to 442,624,426 tons; and the production of petroleum from 35,163,513 barrels of 42 gallons to 183,170,874 barrels.

Obviously these data are not entirely comparable, and, further, the statistics on cordwood consumption on largely estimates. They indicate, however, a decrease in the annual use of firewood of more than 50,000,000 cords, or about 15,000,000,000 board feet.

MISCELLANEOUS.

There are many phases of substitution for wood which have not been discussed because no data are available or the amounts involved are insignificant. The importance of some of the remaining forms of wood utilization in which there has been more or less substitution is indicated by the approximate amounts of wood they consume, including lumber as well as other forest products. These amounts are based upon data secured in studies of wood-using industries conducted by the Forest Service.

TABLE 19.—*Approximate present consumption of various wood-using industries.*

Industry:	Annual consumption in board feet.
Woodenware and novelties	312,000,000
Agricultural implements	321,000,000
Chairs	290,000,000
Handles	280,000,000
Poles	204,000,000
Fixtures	187,000,000
Tanks	175,000,000
Refrigerators and kitchen cabinets	138,000,000
Miscellaneous secondary industries	1,700,000,000
Total	3,607,000,000

The present consumption of the wood-using industries listed is about 3,600,000,000 feet annually, and of this total two-thirds, or 2,400,000,000 board feet is probably in the form of lumber.

There has been on the whole a large amount of substitution for various classes of woodenware and wooden novelties. For example

[1] Consumption of firewood in the United States in 1910.

the old-fashioned wooden pail and tub have been practically replaced by galvanized iron and tinned steel. While no actual data are available upon the substitution in agricultural implements, there is hardly an implement which does not show progressive substitution during the last 25 years, and in many wood has practically been eliminated. Modern harvesting machinery is typical. Its development shows a steady elimination of wood until now very little enters into its construction.

The replacement of wooden poles by concrete is still small. Many types have been developed and short lines set by not a few of the light, traction, telephone, and telegraph companies. So far as is known, however, no general adoption of the concrete pole has taken place. Steel poles and towers have been in use for many years and seem to have become standard for city use by traction companies and for heavy transmission service. No data are available on the extent to which steel and concrete have replaced the wooden pole, but the assumption seems warranted that substitution is comparatively small and not likely to increase very rapidly in the near future. The use of concrete piling for foundation work has become an accepted fact, and it is probable that for this purpose wooden piling will be used in ever decreasing quantities. The steel sheet pile, for cofferdams and similar work, has practically displaced the wooden pile, a displacement which is undoubtedly permanent.

Innumerable metal fixtures are now being substituted for wood. This is true to some extent in the case of handles and chairs, but probably to a smaller degree than for furniture as a whole. The wooden tank has two important rivals, metal and concrete, and of these the former is probably the more important. The wooden windmill tank has practically disappeared and the wooden storage tank for fire protection is following rapidly. The railroad watering tank, too is now made in ever increasing quantities of steel. The concrete tank, especially in small sizes on the farm, is being pushed by cement companies and is replacing to some extent the wooden tank and trough. The steel kitchen cabinet has become an active competitor of the wooden cabinet. The metal sign has come into its own through electric lighting of out-door signs and the cheapening of enameling processes. It is safe to say that the majority of electric signs are entirely metal. Recently, too, the use of metal for bill posting signs and signs along railroad rights of way has come into prominence. The wooden casket has suffered to some extent through the competition of metal caskets. There seem to be two main reasons for this: A demand for expensive caskets like those made of bronze, and the requirement of the Interstate Commerce Commission for the hermetic sealing of caskets in interstate shipments. Otherwise the wooden casket seems to be holding its own.

It has been estimated that 20 or 30 per cent of the toys formerly made of wood are now made of metal. A recent report, however, prepared by a collaborator of the Forest Service states that, notwithstanding the competition of metal, the amount of wood in toy manufacturing is increasing.

The lumber used annually in the manufacture of telephone boxes is a very small portion of the total consumption; however, what is happening is interesting and suggestive. Through the courtesy of one of the largest manufacturers of telephone apparatus, it is possible to present Table 20, showing the output of some of its principal types. The percentage of steel boxes has risen from 5 to 80 per cent of the total within five years. Wooden boxes have fallen in number from 548,300 to 229,950, while steel boxes have increased from 29,900 to 539,450, and the total number made has increased from 578,200 to 769,400.

TABLE 20.—*Telephone-box production of one company.*

Year.	Wooden boxes.	Metal boxes.	Total.
1910	548,300	29,900	578,200
1911	537,025	32,875	569,900
1912	279,240	324,160	603,400
1913	286,550	440,850	727,400
1914	229,950	539,450	769,400

Each telephone box requires about 1 board foot of lumber, so that the total substitution in the case of this company is approximately one-half million board feet.

These are merely examples of miscellaneous cases in which wood is suffering from competition with substitutes. They are given to illustrate present tendencies. The total substitution in such minor uses of wood can only be approximated. In practically all the cases previously discussed it has probably exceeded 10 per cent of the present consumption. This percentage is therefore believed to be conservative. For all forms of wood it amounts to 350,000,000 board feet and for lumber alone to 250,000,000 feet annually.

OTHER CLASSES OF WOOD UTILIZATION.

The third group of wood uses, also miscellaneous in character, is distinguished mainly by the growing consumption of wood; and, in the case of wood pulp and distillates, by great potential importance to the lumber industry as a market for logging and mill waste. Many pulp products are also active competitors of various lumber products. The chemical wood products as a whole offer one of the greatest possibilities for the increased use of timber.

WOODEN-STAVE PIPE.

The use of wooden-stave pipe is distinctive, since the tendency seems to be toward the substitution of wooden pipe for other kinds rather than the reverse. Wooden pipe of one sort or another has been used for many years in city waterworks, the first form being the bored log. Only in comparatively recent years, however, has the use of large stave pipe become common.

Two distinct types of wooden pipe are in general use, continuous stave and machine banded. The former is assembled in place, and consists of wooden staves banded with steel hoops, which are tightened by shoes and nuts. The pipe, as a whole, has no joints in the sense that it is not built in lengths. Machine-banded pipe is built up in lengths at the factory, usually in diameters not greater than 24 inches. It is made from staves and from solid logs properly bored. Continuous stave pipe is usually not made in sizes smaller than 20 inches, though it has been made as small as 10 inches. Lines as large as 14 feet in diameter have been installed, and 6 and 8 foot lines are not at all unusual. United States Department of Agriculture Bulletin 155, from which much of the information in this chapter is taken, states that both continuous and machine-banded pipe are extensively manufactured and used at the present time. One of the principal advantages of continuous stave pipe, especially in the West, lies in its low cost and the ease with which the material for its construction can be procured, transported, and assembled in regions remote from railroads and difficult of access. It has been found impracticable to obtain statistics upon the amount of wood-stave pipe in use at present and upon the rate at which this amount is increasing, but the following paragraphs from Bulletin 155 are illuminating:

More continuous stave pipe has been used for conveying municipal water supplies than for any other purpose.

The Denver Union Water Co. has been using it since 1884 and now has upward of 100 miles installed. Seattle has over 50 miles. Tacoma completed about 43 miles in 1912 and has built more since that time. The Butte City Water Co. prior to 1899 had installed about 30 miles. Walla Walla, Wash., has 13 miles. It is used to some extent at Astoria, Oreg.; Salt Lake City, Ogden, and Provo, Utah; Canon City, Pueblo, Loveland, Trinidad, and Fort Collins, Colo.; and in many other places in the West that might be mentioned, as well as at a few in the Atlantic States.

The use of this type of pipe in connection with power development, though as yet not so extensive, is coming to be even more general than for conveying municipal water supplies, and examples might be enumerated by the hundred of pipes in sizes from 2 feet to 14 feet in diameter that have been installed for this purpose throughout the United States, Canada, Mexico, and Alaska.

The use of wood pipe for irrigation purposes is confined to the Western States, but there are few of the more important irrigation projects of recent development on which it is not employed at least to some extent, its chief adaptability being for "inverted siphons" for carrying water across deep mines or depressions not otherwise easily

spanned. In a few instances the original gravelly ditches have been entirely supplanted by continuous stave pipe. It is also very frequently used for conducting water from pumps to the points of discharge into ditches or reservoirs at higher elevations.

There seems to be a definite field for wooden water pipe for municipal water supply, in irrigation projects, and in various places where chemicals in the water prevent the use of metal pipe. A steady expansion of this use may be expected in the future. No specific data on the rate of its present increase are available.

PAVING.

The use of wood blocks as a paving material is not new in the United States.[1] During a period of 60 years prior to 1895 untreated wood blocks were laid in comparatively large quantities, but in general

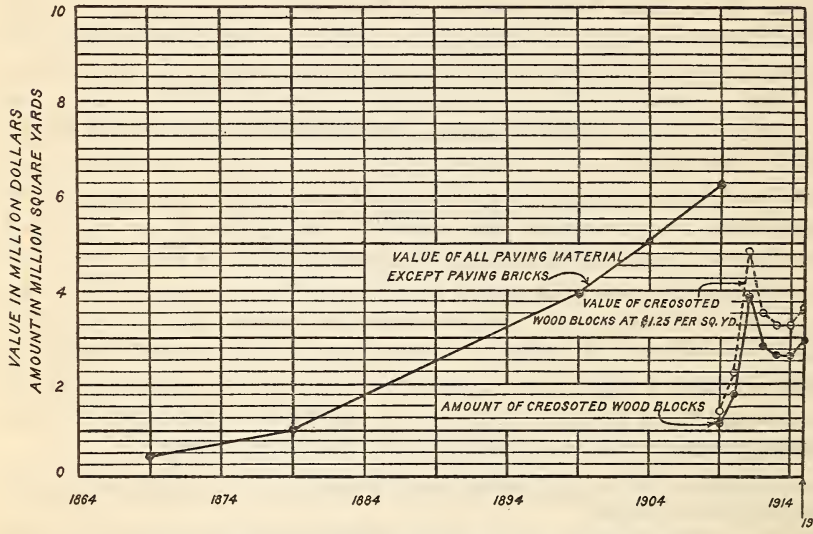

FIG. 27.—Amount and value of paving material in the United States.

proved objectionable, mainly because of a tendency to decay rapidly. The use of treated blocks began about 1875 and increased slowly until about 10 or 15 years ago. Since that time the use of the creosoted block has on the whole grown rapidly, and represents a form of utilization in which wood seems to be able to increase its markets in competition with other materials. The use of the treated paving block has grown in answer to the demand for a noiseless, clean, durable pavement which can be maintained easily and cheaply. It has been handicapped in competition by its initial cost, which is higher than for most other pavements, and by its tendencies to "bleed" and expand and to become slippery when wet.

[1] History of treated wood block pavements in the United States. Report of the committee on wood block paving of the American Wood Preservers' Association, Jan. 19–21, 1915.

As might be anticipated from the growth of American cities, there has been a regular increase in the total value of paving materials produced. This is shown for all paving materials except bricks in figure 27, which is based upon the Census of 1910. The following are included:

All kinds of paving blocks, and paving materials, mixed and unmixed, for streets or floors, are produced by establishments in this classification. The blocks are made of asphalt, bituminized brick, cedar, hardwood, creosoted wood, bluestone, cement, concrete, copper ore, granite, and limestone. The unmixed paving materials reported include crushed furnace slag, granite and limestone, distillates, dry natural asphalt, and pitch, tar, and coal-tar oil. The mixtures include artificial asphalt, asphalt paving mixture for top coat and binder, bituminous and other cement, liquid asphalt, and tar concrete.

The production of paving brick increased steadily until 1909, as shown by figure 28, since which there has been a slight falling off.

Separate data on creosoted blocks are available for only a few years. The curves showing the amount and value of wood blocks

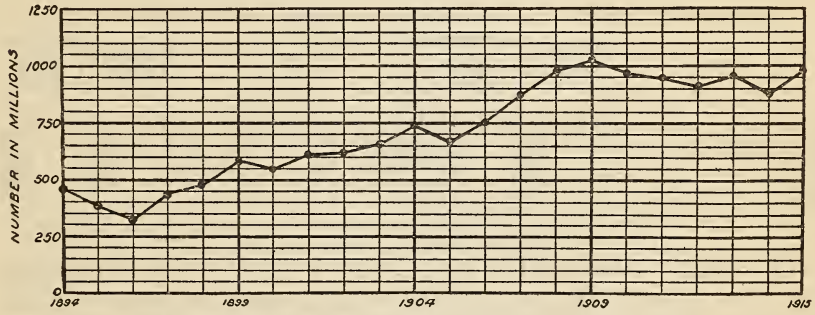

FIG. 28.—Production of vitrified paving brick in the United States.

creosoted, in figure 27, are based upon data collected by the Forest Service in cooperation with the American Wood Preservers' Association and published by the association.[1] The increase between 1909 and 1911 was from slightly more than 1 million to nearly 4 million square yards; while in 1915 the total was slightly less than 3 million square yards. Since the quantity of blocks creosoted might not follow closely the wood-block paving actually laid, the Forest Service in 1915 requested from the city engineers of all towns in the United States having a population of over 5,000 a statement of the amount of wood-block paving laid during a series of years. Table 21 shows a maximum of 2,112,152 yards in 1913, with a very slight falling off in 1914. The increase between 1909 and 1914 amounts to more than 200 per cent. The total paving laid in the principal cities of the United States in 1913 was approximately 33,000,000 square yards, so that the treated wood block represents about 6 per cent.

[1] Quantity of wood preservatives consumed and amount of wood treated in the United States in 1914.

TABLE 21.—*Treated wood-block paving laid in the United States.*

	Square yards.
1914	2,090,424
1913	2,112,152
1912	1,666,097
1911	1,156,228
1910	1,019,307
1909	658,992
Prior to 1909	1,781,447
Year not specified	1,820,555
Total	12,305,201

The data in Table 22, taken from various issues of the "Municipal Journal" and converted to percentages in order to be comparable, show essentially the same development. The maximum percentage of 5.38 in 1909 exceeds but slightly those of 1911 and 1913, which were 4.98 and 4.95, respectively.

TABLE 22.—*Percentage of wood block to total paving.*

Year.	Number of cities.	Percentage of wood block.	Year.	Number of cities.	Percentage of wood block.
1907	444	2.92	1913	650	4.95
1909	136	5.38	1914	707	4.35
1910	349	2.87	1915	997	2.37
1911	460	4.98	1916	943	1.69
1912	424	4.52			

The falling off indicated in both Tables 21 and 22, which began in 1914, was undoubtedly, in its initial stages, caused by the war which at various times has cut off importations of creosote from Europe.

If such difficulties as bleeding and swelling can be overcome, and investigators are very hopeful of accomplishing this and indeed may already have done so, there is apparently no reason why the consumption of wood paving blocks should not increase largely in the future.

WOOD PULP AND CHEMICAL PRODUCTS.

The tendencies in the manufacture of wood pulp are of public significance and of importance to the lumber industry. Much of the present waste in lumbering operations is suitable for pulp making so far as the material itself is concerned. The waste now so utilized does not, however, constitute more than 8 per cent of all the raw material consumed. A much larger use of this waste is a distinct possibility and would be an economic gain of great public and industrial importance. It would serve to offset in the lumber industry, in part at least, the effect of the growing substitution of pulp products for lumber.

The pulp industry, because of the substitution of its products, has also a direct bearing upon the use of wood in other forms than lumber. Pulp products are also being substituted for other materials than wood. It seems probable that the use of wood for pulp has almost unlimited possibilities. During recent years, for example, a large number of extremely varied pulp or cellulose products have appeared on the market, including fabrics, rugs, artificial silks, rope twine, etc., in addition to products such as fiber board, which have already been mentioned.

The consumption of pulpwood, from the census data given in Table 23, has grown from 755,000 cords in 1889 to 4,470,763 in 1914, and the increase is practically unbroken.

TABLE 23.—*Consumption of pulpwood in the United States.*

	Cords.		Cords.
1889[1]	755,000	1908	3,346,953
1899	1,986,310	1909	4,001,607
1905	3,192,223	1910	4,094,306
1906	3,661,176	1911	4,328,052
1907	3,962,660	1914	4,470,763

While the use of wood in the distillation of hardwoods during the last 10 years has remained practically stationary, the output of its products has materially increased due to the improvement of plants and processes. More than one-third of the present annual consumption of wood is waste from lumbering operations, and there is a possibility of increasing this proportion with advantage to both industries.

The consumption of hardwoods for distillates as shown by census and Forest Service reports has increased from 676,759 cords in 1905 to 1,204,151 cords in 1914, the increase occurring largely between 1905 and 1906.

Other industries now of importance to the sawmill in furnishing an outlet for by-products which would otherwise be wasted and hence offsetting in part the effects of substitution are (1) softwood distillation with a present annual consumption of from 150,000 to 200,000 cords and (2) the tanning industry with a consumption in 1909 of approximately 700,000 cords of hemlock bark, 300,000 of oak bark, and 12,000 cords of chestnut acid wood.

For a full discussion of the possibilities in these industries, the reader is referred to "The Utilization of Low-grade Lumber and Mill Waste" by Howard F. Weiss, one of the publications in the series of reports on the lumber industry in preparation by the Forest Service.

[1] Census estimates 96,640,000 cu. ft., 128 cu. ft.=1 cord.

CONCLUSIONS AND SUGGESTIONS.

Estimates on the substitution for wood can at best merely approximate the situation in most cases because of the difficulty, under complex building and economic conditions, in deciding where substitution begins and leaves off, and, further, because often only incomplete statistics are available, and sometimes none at all. Estimates summarized below which are purposely conservative, are believed to be less than the actual substitution which has taken place.

REPLACEMENT IN VARIOUS FORMS OF USE.

General building and construction used in 1915 about 27,000,000,000 feet board measure out a total lumber consumption of 38,000,000,000 board feet. Substitutes, mainly concrete, steel, brick, and other clay building products, have probably absorbed markets formerly supplied by lumber amounting to at least 4,050,000,000 board feet annually, and the bulk of this replacement has occurred during the last 15 years. Since 1900 the production of cement, steel, and clay building products has increased 140 per cent or more. The production of brick and lumber is practically the same now as in 1900. Lumber has fallen off 15 per cent since 1907, the year of its maximum production. The extent of the substitution is further emphasized by the fact that building construction in the entire country between 1907 and 1913 continued to increase rapidly, while lumber, constituting more than all other competing materials combined, fell off regularly. The decline in the production of lumber was, however, more than made up by the increased production of its principal competitors. Most considerations, economic as well as statistical, indicate an increasing substitution for lumber in building and construction.

The replacement of the board fence by barbed and woven wire reached its present stage considerably in advance of the general substitution movement. The use of a small amount of lumber in certain types, such as the picket and tight board fence, may be expected to continue indefinitely. Replacement of the wooden-rail fence by various wire fences began early and will continue for many years, particularly in the newer agricultural regions in which timber clearing is still in progress. A material replacement of wooden posts, round, split, and sawed, by steel, and particularly by cement, is recent and most extensive in regions of limited timber supplies. The total substitution for wooden fencing, including lumber, posts, and rails, is estimated at 3,550,000,000 board feet annually, and for lumber fencing alone at 1,000,000,000 board feet.

Replacement of the lumber sidewalk, mainly by cement, also took place in advance of the general substitution movement. It is so

complete that lumber has practically withdrawn from this field. The amount of substitution can only be approximated, but must reach at least 600,000,000 board feet annually.

Because of the competition of prepared and ready roofings, slate, metal shingles, and tiles, asphalt shingles, clay tile, and cement tile, important in the order named, the normal increase in the production of the wooden shingle has been prevented since 1904; and production may even have been decreased as much as 37 per cent. About 50 per cent of all roofing manufactured now represents substitution. The increase in the production of substitutes from 1904 to 1914 was 200 per cent, and promises to continue. Much of the substitution, which is equivalent to approximately 1,440,000,000 board feet of timber annually, has occurred during the last 10 or 15 years.

Wall and plaster board have been the greatest factors in replacing wooden lath, a by-product of lumber manufacture. Lath production fell off, by 1915, nearly 30 per cent of its maximum output. On the other hand, between 1904 and 1914, wall and plaster board production increased 6,745 per cent, and between 1909 and 1914 more than 300 per cent. Substitution for lath, which has taken place almost entirely during the last ten years, now amounts to approximately 210,000,000 feet of timber annually, and promises to increase. A part of this substitution, however, involves the use of wood pulp in the form of wall board.

Approximately 3,850,000,000 feet board measure of lumber was used in 1912 in the manufacture of boxes. The principal competitors of the wooden or shook box are the veneer box and fruit and vegetable package and the fiber container. The results of competition between these types of containers can only be approximated. Apparently the production of all three types increased between 1905 and 1912, the years for which the best data exist. But shook-box production has probably lost ground to its competitors during the last 10 years to the extent of approximately 1,500,000,000 board feet annually.

Railroad-car construction has been revolutionized during the last ten years. The average amount of lumber used per freight car has fallen 58 per cent since 1900, from 5,140 to 2,160 board feet, and from 1905 to 1915 the number of all-wood freight cars built fell more than 99 per cent. A similar change occurred in passenger-car construction, but the number of cars ordered was small. The total substitution for lumber amounts roughly to 260,000,000 board feet on the small orders for 1914.

Metal furniture now replaces 175,000,000 feet board measure of lumber annually. Its production is largely a growth within the last decade. While the production of metal furniture is likely to increase, it seems doubtful if this will prevent an increase in the amount of lumber used in furniture making.

Between 1904 and 1914, through the competition of the automobile, the production of horse-drawn vehicles fell off 55 per cent, or 770,099 vehicles from a maximum yearly production of 1,711,330. This revolutionary change in type of construction has probably reduced the consumption of wood in the vehicle industry as a whole. Furthermore, metal now replaces annually a total of approximately 30,000,000 board feet in this field of use.

The replacement of lumber in shipbuilding by iron and steel began early and has taken place slowly. The present consumption of lumber in this industry is approximately 200,000,000 board feet yearly, and the present substitution approximately 150.000,000 feet, although the basis for any estimate is unsatisfactory.

Only one-half of the 40,000 silos now constructed annually are of lumber. This involves a total displacement of approximately 50,000,000 board feet of lumber yearly. The proportion of substitute silos seems to be increasing, but not rapidly enough to prevent an increase in the amount of lumber used for this purpose.

The replacement of the wooden windmill has been comparatively slow, and during the last 15 years has not exceeded approximately 5 per cent. About 77 per cent of the 131,200 mills now constructed annually are of steel, a total substitution for lumber of about 25,000,000 board feet per year.

The general effect of the large substitution in making both tight and slack cooperage and of other economic developments affecting their manufacture has been to prevent an increase in production rather than actually to reduce the present output. The oil industry, the largest potential user of tight cooperage, now depends largely upon metal containers. The use of tight cooperage for liquors seems to have been restricted somewhat by the glass bottle and the prohibition movement. The normal increase in slack cooperage has been taken up by the metal slack barrel, the veneer barrel, cotton, jute, and paper sack, the wooden box, and the fiber box and carton. While the production of both tight cooperage, now amounting to about 17,000,000 barrels annually, and of slack cooperage, now amounting to about 100,000,000 barrels, has been increasing slowly, a further increase amounting to at least one-third of the present output has undoubtedly been taken over by competitors. In board measure this is equivalent to 325,000,000 feet.

For fuel, the greatest single use of wood in the United States, the very approximate data available indicate a decreased consumption since 1880 of more than 50,000,000 cords annually, equivalent to about 15,000,000,000 board feet.

Additional replacement to the extent of 250,000,000 feet annually of lumber and 350,000,000 feet of wood in all forms covers miscella-

neous uses of wood. Such uses now account for approximately 2,500,000,000 board feet of the yearly lumber consumption and 3,600,000,000 feet of the total wood consumption.

The use of lumber for stave pipe and paving blocks seems to be increasing in competition with other materials. The steadily increasing use of pulp wood now approximates 4,500,000 cords yearly, or 1,500,000,000 board feet. Wood distillation has remained stationary during the last decade, although improved plants and processes have largely increased the output of two of its principal products.

THE AGGREGATE DISPLACEMENT OF LUMBER AND WOOD.

The total estimated replacement of lumber in all forms of use, as summarized in Table 24, reaches 8,090,000,000 board feet, or 21 per cent of the lumber consumption of the United States in 1915. This figure could probably be raised 2,000,000,000 or 3,000,000,000 feet and still be within the actual substitution. The rate of substitution seems to be increasing and is now in excess of 500,000,000 board feet a year.

Sixty per cent of this replacement has probably occurred during the last 15 years, and possibly one-half during the last 10 years. Approximately 70 per cent of the present cut of lumber goes into forms of use whose demands appear to be decreasing. Twenty per cent more of the cut, including the sawed timber used by railroads and that manufactured into shook boxes, goes into strongly competitive fields in which future tendencies are more or less doubtful. In the remaining 10 per cent of wood uses, including furniture, silos, paving blocks, and stave pipe, there seems to be a much greater opportunity for increased consumption. These estimates are necessarily based largely upon past tendencies.

The estimated substitution for wood in all forms, including lumber as set forth in Table 24, amounts to approximately 27 715 000 000 board feet annually.

The total displacement of lumber and other forms of wood is already large, and the general trend is toward increasing substitution. The situation, however, is but partly one of replacing various wood products in their old markets. Of great importance also are the numerous changes in the character of construction to forms to which wood is not suitable and which limit the opportunities for its use. No attempt has been made to determine the extent of present limitations of this kind, although it is undoubtedly large, and, as in the case of actual replacement, promises to become greater.

TABLE 24.—*Estimated present annual substitution for wood in all forms and for lumber.*

Class of use.	Competitors.	Substitution.	
		For wood in all forms, including lumber.	For lumber.
		Board feet.	*Board feet.*
Building and construction, exclusive of the four following classes.	Steel, brick, concrete, asphalt, etc	4,050,000,000	4,050,000,000
Fencing	Barbed and woven wire, steel and concrete posts.	3,550,000,000	1,000,000,000
Sidewalks	Cement	600,000,000	600,000,000
Roofing	Metal, tile, slate, asphalt, asbestos, etc.	1,440,000,000	
Lath	Metal lath, wall and plaster boards	210,000,000	
Boxes	Fiber and veneer	1,500,000,000	1,500,000,000
Railroad cars	Steel	260,000,000	260,000,000
Furniture	Steel and other metals	175,000,000	175,000,000
Vehicles	Metal	30,000,000	30,000,000
Ships	Steel	150,000,000	150,000,000
Silos	Tile, concrete, brick, steel, etc	50,000,000	50,000,000
Windmills	Steel	25,000,000	25,000,000
Cooperage	Steel, veneer, wooden boxes, paper and cotton sacks, etc.	325,000,000	
Miscellaneous		350,000,000	250,000,000
Fuel	Coal and oil	15,000,000,000	
Total		27,715,000,000	8,090,000,000

CAUSES OF SUBSTITUTION.

The replacement of wood products by cement, steel, and other materials, including various new forms of wood itself, is not altogether a superficial movement which can easily be counteracted by the industries concerned. It is in some respects based upon fundamental economic and social changes which have been taking place in the United States during the last 25 years, and which are still under way. In other respects it is dependent upon conditions which can be modified to a greater or less extent by the wood-producing industries. While advantage of many of these changes has been taken skillfully by substitute industries, fundamental economic causes lie in the movement of population from country to city, with all of its effects upon land values and rentals, construction demands, public regulation of buildings, and like factors; in the completion of preliminary building in many agricultural regions and the resulting tendency toward forms of construction regarded as more permanent; in the gradual reduction of the more accessible supply of timber and the discovery of new sources of supply of its competitors; in the "safety first" idea, which in 14 years, along with other factors, has reduced the utilization of lumber in cars by nearly 60 per cent.

Ordinarily competition centers upon the initial and ultimate cost of construction and accepted beliefs as to the utility of different materials. More than 75 per cent of the replacement of lumber has taken place in spite of the fact that the initial cost of the substitute has been higher. This, in general, holds true in building and construction, railroad cars, furniture, ships, silos, and many miscellaneous

uses. Replacement has been aided by the lower initial cost of the substitute in boxes, vehicles, and in some of the miscellaneous products. Substitutes for shingles, lath, and tight cooperage cost more than the wooden article they displace, while substitutes for slack cooperage ordinarily cost less. Many of the general price movements have tended to aid substitutes at the expense of wood. Wholesale-lumber prices have risen during the past 25 years, especially prior to 1907, while brick prices have fallen 7 per cent, bar iron 15 per cent, and cement prices 54 per cent. Much more exact knowledge has been available concerning the properties of substitutes than of wood, and hence of their comparative utility. This has resulted partly from aggressiveness of substitute industries, also manifested in many phases of merchandising and special service to consumers. Mechanical inventions have also stimulated the replacement of wood—the steam engine in shipbuilding, the gasoline engine in the vehicle industry, and the pipe line, steel storage tank, and tank car in the transportation and refining of oil and its products.

In the past the lumber industry has lost ground because of a mistaken belief in an unchanging demand for its products in present-day civilization, because of an individualism exceeding that of any of the great American industries with the possible exception of agriculture, and because of a general failure to appreciate the magnitude of the inroads upon its markets made by substitutes. Lumber has undoubtedly suffered in competition because of the varying standards of manufacture, complexity in grades and specifications, and confusion in trade names.

SUGGESTIONS.

The lumber industry may not be able, and in some cases probably should not attempt, to counteract the economic influences which are restricting the use of its products. For some purposes it is known that other materials are better suited than wood, and the use of substitutes will undoubtedly grow. Because it deals with a natural product, the lumber industry has comparatively small leeway for modifying or improving the properties of wood, while the properties of competing manufactured substances may be more radically changed.

Within the uses for which wood in lumber or other forms is suited, however, much depends upon how fully its characteristics and properties are known. This involves exact knowledge which can be gained only through scientific research in the broadest sense of the term. No great industry under modern conditions of competition can long hold its place without thoroughgoing investigations of its raw material, its processes, its cost of production, its products, and its wastes. A number of industries in the United States to-day much smaller than the lumber industry, as measured by the value of their

output, are devoting sums exceeding $1,000,000 annually to research.

Knowledge of the structural, mechanical, physical, and chemical properties of wood are basic to its proper use, and the lumber industry should either make provision for tests to obtain such data, or, as a minimum, cooperate to the fullest extent in their practical application when obtained by other agencies. Among such tests, for instance, are those of the structural properties, to make it possible to distinguish one wood from another; of the mechanical properties, such as the bending and compressive strength, shearing, stiffness, toughness, specific gravity, etc., to make possible a scientific basis for grading rules and specifications, building codes, etc.; of the physical properties, to permit the most efficient methods of seasoning; and of the chemical properties, to indicate valuable by-products and make possible the profitable utilization of waste. Exact data should be available on durability under different conditions and on methods of preservative treatment, as well as on other means of improving the natural qualities of wood. It is no more possible to use wood intelligently and economically without such knowledge than it is to use steel or cement.

If limitations in the market price of lumber are imposed by competing substitutes, the lumber manufacturer is compelled to earn his profits through better utilization, the development of by-products, better merchandizing methods, and reduced costs of production. As a basis for reducing costs of production, thoroughgoing efficiency studies of operating methods and costs are necessary.

The total woods and mill waste[1] incident to the production of 40 billion feet board measure of lumber is estimated at 61,600,000 cords of solid wood, bark, sawdust, slabs, edgings, trimmings, etc. A part of this waste can not be avoided under present economic conditions. Approximately one-half of the lumber produced may be classed as low grade, with relatively high producing costs and low returns. The problem of reducing woods and mill waste and turning low-grade lumber into more profitable forms of use is one which can in part be solved by the lumber industry and in which some progress has already been made. One means to this end is greater efficiency in the woods and at the mill. Much low-grade lumber can be diverted to other products through remanufacture at the mill into forms which will supply local or general needs. There is a growing possibility of using waste for a wide range of known products, such as posts, mine timbers, ethyl alcohol, wood alcohol, acetate of lime, producer gas, wooden novelties, in addition to the common use for fuel. One of the greatest possibilities is for pulp and pulp products. No known crop can compete with the forest in the bulk production of

[1] "Utilization of Low-grade Lumber and Mill Waste," by Howard F. Weiss.

cellulose. There are unquestionable possibilities of profitable utilization of wood waste and low-grade lumber which can not now be foreseen. Within this field the wood-using industries have an opportunity for great advancement. Some of the most successful industries in the United States to-day are largely dependent for their prosperity upon the progress they have made in the profitable utilization of their waste and low-grade products.

A permanently successful industry must be thoroughly familiar with the statistics of production and consumption and with the economic considerations affecting them.

Lumber is no longer a necessity and must be sold largely in competition with other materials, hence merchandising methods at least as modern and efficient as those of its competitors are necessary. This involves effective advertising, well-standardized manufacture, grading rules which consumers can understand and which meet their actual needs, together with a thoroughgoing scientific as well as practical knowledge of the product, an inspection service which insures delivery to purchasers in accordance with specifications, and an organization which makes possible the adjudication of difficulties outside of the courts. If, as in the case of the wooden silo, lumber has lost half of its market largely through the aggressive merchandising of its competitors, further loss may at least be reduced through exact knowledge of the proper manner in which to build wooden silos and by getting this knowledge effectively into the hands of prospective builders. If the wooden shingle has lost half its market mainly through its susceptibility to fire and the capital which has been made of this fact, the most logical method of preventing further loss would be to make the wooden shingle fire resistant. Competing industries have probably undertaken and solved problems at least as difficult.

Many of the activities which are necessary to secure for lumber the place in trade to which its properties and characteristics entitle it are among the legitimate functions of trade associations and can be undertaken to better advantage by the association than the individual: Regional advertising and the advertising of the value of products for particular purposes and similar features of aggressive merchandising; the establishment and maintenance of lumber grades and specifications, with such special services as responsible inspection; the adaptation of the forms and methods of manufacture to the requirements of the trade; studies of efficiency in all of its ramifications; the furnishing of scientific information along various lines to the public and of special information concerning trade conditions to the industry; and the research necessary to secure basic data. With adequate safeguards through control by some such agency as the Federal Trade Commission and through publicity, associated efforts should be encouraged to secure efficiency in the industry.

PUBLIC CONSIDERATIONS.

The public should see that it has an effective administrative machinery for protecting its own interests which may be involved in the associated efforts of the forest industries. The public is also interested in the price limitations on lumber imposed by the competition of substitutes. The establishment of price levels for certain products by the competition of substitute materials will afford some protection to the public against combinations or unwarranted increase in lumber prices through the joint action of manufacturers. To a degree also these considerations apply in the case of other wood products.

The total replacement of lumber and wood by other materials is large, and apparently is growing. In addition, the use of wood is being increasingly limited to an unknown extent by changed forms of construction for which wood is not suitable. These tendencies toward the decreased use of wood are in part offset by rapidly growing demands for some of the newer wood products, such as pulp. The public is interested in the extent of these changes and in their future developments. They have a very direct bearing upon the question of timber production. It is certain that there will be need for all of the timber in the United States. The total consumption has for many years been far in excess of growth, and the situation promises to continue. Already in many regions timber shortage and high prices have followed the exhaustion of the local supply. From the public standpoint the tendency toward substitution does not do away with the need for the large-scale growing of forests, vastly larger than any now planned for or contemplated.

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PUBLICATIONS ON THE LUMBER INDUSTRY.

A study of conditions in the lumber industry was conducted by the Forest Service of the United States Department of Agriculture in cooperation with the Bureau of Corporations and the Federal Trade Commission during 1914 and 1915. Its object was to obtain and place before the public in a constructive way the essential facts regarding this industry and their bearing upon forest conservation. As part of the cooperative plan, an investigation of the export lumber trade was undertaken by the Bureau of Foreign and Domestic Commerce.

The following are bulletins on the lumber industry which the Department of Agriculture plans to publish:

Some Public and Economic Aspects of the Lumber Industry. By William B. Greeley, assistant forester.

A summary of the study compiled largely from data obtained by the authors of the more detailed reports dealing with particular regions or phases of the lumber industry.

Forestry and the Lumber Industry. By Henry S. Graves, Forester.

A résumé of the practice of forestry in the United States; the methods of forestry applicable under varying economic and industrial conditions; the public aspects of private forestry; and the place of forestry in the lumber industry.

Timber Ownership and Lumber Production in the Southern Pine Region. By C. Stowell Smith, Assistant District Forester.

Timber Ownership and Lumber Production in the Douglas Fir Region. By Austin Cary, Logging Engineer.

Timber Ownership and Lumber Production in the Inland Empire. By David T. Mason, professor of forestry at the University of California, formerly Assistant District Forester in the Forest Service.

Timber Ownership and Lumber Production in California. By C. Stowell Smith, Assistant District Forester.

These four reports deal with the standing timber in the regions having the largest supply, the cost and value of stumpage, costs and returns in lumber manufacture, and the conditions existing in timber ownership and lumber production.

Public Timber and Its Use. By William B. Greeley, Assistant Forester.

A synopsis of the origin and history of the public timberlands, their present extent and character, their use under existing laws and regulations, and the policies which should govern their administration.

The Distribution of Softwood Lumber in the Middle West. Wholesale Distribution. By Ovid M. Butler, Assistant Director, Forest Products Laboratory.

The Distribution of Softwood Lumber in the Middle West. Retail Distribution. By Ovid M. Butler, Assistant Director, Forest Products Loboratory.

A study of lumber wholesaling and retailing in 11 of the Central States, including their costs and returns, retail and wholesale prices, lumber freights, and the division of the retail price of lumber among the various agencies concerned in its manufacture and distribution.

The Utilization of Low-Grade Lumber and Mill Waste. By Howard F. Weiss, formerly Director of the Forests Products Laboratory.

A study of the amount of low-grade lumber now produced and of mill waste, their bearing upon lumber manufacture, and possible means of putting them to more profitable use for paper, distillates, and other by-products.

The Substitution of Other Materials for Wood. By Rolf Thelen, Engineer in Forest Products.

A brief historical and statistical résumé of the replacement of wood by other structural materials.

The Adaptation of Lumber Manufacture and Grading to the Requirements of Consumers. By Harold S. Betts, Engineer in Forest Products.

A study of the possibilities of greater efficiency in adapting lumber manufacture to the ultimate use of the product and the specific needs of various classes of consumers.

The Department of Commerce also has in preparation a bulletin on "The Exportation of American Lumber," by Dr. Edward E. Pratt, Chief of the Bureau of Foreign and Domestic Commerce.

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